

Exhibit 2



CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231, on 3/15/99

Julie Bell

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re PATENT application of:)
April Gulbrandson KOHRT) Examiner: H. T. Vo
Serial No. 08/951,754) Art Unit No. 3747
Filed: October 16, 1997)
For: INTAKE AIR HEATER AND)
AIR DELIVERY ASSEMBLY)
FOR ENGINES)
)

Honorable Assistant Commissioner for Patents
Washington, D.C. 20231

DECLARATION OF SEAN C. MILLOY

I, SEAN C. MILLOY, declare as follows:

1. Since November 1981, I have been employed by Cummins Engine Company as an engineer.
2. During the period covering the design and development of the subject invention, I was the Chief Engineer of the C-Series Engine.
3. In my capacity as Chief Engineer I was responsible for overseeing the design and development of the C-Series Engine. In the regular course of my business practice, I compiled a monthly report called Newsnotes, consisting of the development highlights on the C-Series engine for the

previous month. To compile each monthly report I would request inputs from the C-Series Engine Design Leader, Performance Leader and Mechanical Development Leader, and redraft their inputs into a consolidated status report.

4. Attached at Exhibits A-F are true and accurate copies of the C-Series Newsnotes for the relevant period. These reports were kept in the regular course of business, and were regularly updated at or near the dates indicated on the reports. Further, as part of my regular practice, the date indicated on each report accurately indicated the date on which the report was released. These reports generally reflect the highlights of the activities being engaged in by individuals working on this project, under my direction.

5. As can be seen from these reports, April Kohrt diligently and continuously worked on the Intake Air Heater Development project during the periods indicated on these Newsnotes reports.

6. The document attached at Exhibit A is a true and accurate copy of the C-Series November 1993 Newsnotes. Page 3 of Exhibit A clearly states that Komatsu requested the use of a grid heater on the C-Series Engines to avoid the use of ether as a cold start device. The request from Komatsu is what initiated the subject development effort.

7. The document attached at Exhibit B is a true and accurate copy of the C-Series December 1993 Newsnotes. Page 2 of Exhibit B again addresses the motivation behind the Intake Air Heater Development project.

8. The document attached at Exhibit C is a true and accurate copy of the C-Series January 1994 Newsnotes. Page 3 of Exhibit C clearly states that design work on a grid heater design for the 6CTA is complete and samples have been ordered from Phillips & Temro. It is obvious from this entry that Phillips & Temro was the recipient of at least a portion of the Cummins design documentation relating to the Intake Air Heater.

9. The document attached at Exhibit D is a true and accurate copy of the C-Series February 1994 Newsnotes. Page 3 of Exhibit D provides that the increased height of the engine to accommodate the grid heater is unacceptable. It is at that time that the focus of the Intake Air Heater Development began shift toward investigating options that would not require increasing the height of the engine envelope.

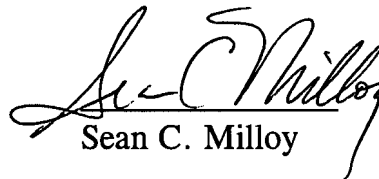
10. The document attached at Exhibit E is a true and accurate copy of the C-Series May 1994 Newsnotes. Page 3 of Exhibit E addresses another development issue that arose with respect to the grid heater design.

11. The document attached at Exhibit F is a true and accurate copy of the C-Series June 1994 Newsnotes. Page 4 of Exhibit F clearly provides that the design work on the grid heater has been diverted to explore the capability of mounting the grids inside of the air box (intake manifold). This particular effort was directed at reducing the height of the heater/engine combination and improving access to the injectors.

12. The documents attached at Exhibit G are true and accurate copies of the August - October 1994 and December 1994 C-Series Newsnotes. As is clear from the documents in Exhibit G, the development effort continued on the C-Series Engine (which included the subject intake air heater) at least until December 1994.

13. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: 3/1/98


Sean C. Milloy

DATE: December 10, 1993
TO : DIST-C
DIST-PESEDC
FROM: S.C. Milloy
SUBJECT: C Series November Newsnotes

1994 Introduction

The C Series passed the M5 management review in November with the following Midrange engineering issues highlighted:

- * Delay of certification the 300-C Rating
Since the M5, certification of this rating has been completed on the revised schedule and release of this rating is still being worked.
- * Amount of field test time on "production" intake heater hardware
While we have been through one winter season with prototype hardware, we do not have enough field test time on production hardware to understand differences achieved in the field from improvements made in the design.
To gain results quicker, additional field test units have been chosen for this winter at COTA(Columbus Ohio transit authority). Currently, 67 C powered transit buses are being upfit with hardware which has been programmed to cycle every time bus is started to accelerate the test.
Other field test units are being upfit as well to gather more data.

Certification is now complete on all three 94C engine families. During November the 300C family successfully completed Certification. The final certification results for all three families are as follows:

Family	Rating	PM	NOx
413E	300C	.08	4.8
413F	High Torque	.066	4.48
413G	Low Torque	.087	4.79

The 94C 300hp rating was revised just prior to Certification testing due to problems with secondary injections at rated. The problem was resolved by changing the CV delivery valve retraction from 150mm3 to 180mm3. Vehicle testing in a Ford LN8000 tractor with 60,000 gvw produced no idle instabilities, and low idle backup appeared to be adequate. Idle stability was a concern in changing to the higher retraction delivery DV. A full vehicle drivability and stability test will be scheduled with CTC as soon as more fuel pump samples are available.

ISIR of 94C 210 and 225 hp ratings is in process at CDC and METC. Initial data indicates adjustment of full load fueling will be necessary for both ratings. Emissions testing at METC of a 210HP engine has indicated NOx emissions are higher than expected. Cylinder head swirl and test cell measurements are being investigated. Particulate emissions appear to be in the around 0.08 as expected.

Transit Bus

Certification has been completed on the 94 Transit Bus product. Due to emissions compliance issues with the 275Hp/860ft-lb and 250Hp/660ft-lb ratings, the 275Hp/800ft-lb rating will be the only rating released for Jan94

production. The more stringent PM (.07 g/BHp-hr) and Curb Idle Torque requirement which negatively impacts NOx are the reason for not offering the other ratings at this time. The transit bus certification levels are:

Rating	PM	NOx
-----	-----	-----
275/800	.048	4.68
Regulation	.07	5.0

Transient response of the transit bus product is the only significant field issue at this time. The use of #1 fuel has been identified as a major contributor to the poor response. The majority of bus authorities use #1 fuel to limit smoke/emissions on past diesel products. Engineering is developing a transit bus rating specifically for #1 fuel only that will achieve the same level of response as the #2 fuel rating with the same emissions levels. This will require a separate rating under the same emissions family.

Other issues to address the transient response have been identified and resolved. Changes include increasing rear end ratio on all future bus builds and improve system throttle response.

EDISON/RP43

The Edison RP43 program is now progressing towards the following lead rating availability dates

C Series automotive..... January, 1996
C Series industrial..... July, 1996
C Series Case October, 1996

There will not be any B Series electronically governed ratings released ahead of Encore.

Edison RP43 incorporates two new key features desired by automotive customers: injection timing control and J1939 datalink. These two features will allow the C Series to attain improved fuel economy through timing control and the J199 data link will be compatible with automatic-manual transmissions (AMTs) now under development by Eaton and Dana.

Several extensive changes are required to apply the RP43:

* NBF needle movement sensor	*TDC sensor
* wiring harness	* rear tail support
* high pressure fuel lines	* low pressure fuel lines
* ductile iron gear case	* CM520 circuit/software changes
* EHAB shutdown valve	

Design work is progressing on the Edison II concept drawings for the RP 43 fuel pump mounting. A ductile iron gear housing will be designed and procured for this project as the current aluminum housing is marginal for the increased load. Thus far, with a slight modification to the pump, both the Bendix 550 (used by Ford) and the Holset QE compressors will fit with the RP 43. The Midland compressor would require a large cut out on the pump and this is being studied further.

Industrial Emissions

Development of the 260Hp #1 curve for the 6CTA has resulted in excessive peak torque due to the natural hydraulics of the P3000 fuel pump. Several attempts by Bosch to revise the pump specifications have failed to provide the torque reductions needed to reduce thermal loading at peak torque. Two options are available to correct the situation.

- Utilize a RKQK governor which provides for negative torque control. The RQVK would also provide reduce throttle pedal forces (RSV is very stiff) and low speed stability improvements over the RSV. However, the RQVK is a significant cost penalty (approx \$200).
- Utilize the LDA to control fuelling from 1600rpm and below. This would require an increase in peak torque speed from 1500 to 1700rpm. This would also reduce NOx and possibly allow for an increase in engine timing to improve BSFC and heat rejection. Engineering are investigating this option with the applications and marketing groups to understand if any application issues exist.

Industrial Emissions work on fuel pump lines, FE lines and drain lines is progressing. Komatsu is requesting the use of a grid heater on these engines to avoid the use of ether as a cold start device. A proposal to use either the grid or a spacer has been made to Industrial Applications. This would decrease proliferation by having only one set of fuel lines, etc. However, this has a 1.5 inch impact on engine envelope which is being studied by Applications.

6CT Emission Program -

We have now successfully met all of the power, smoke and emission targets for the CT product. We are however, 15 points higher than anticipated BSFC. Current BSFC puts us at 0.400 lb/hp-hr. Looking at ways to improve BSFC. We received from Holset a new 17cm2 turbine casing equipped with EWM. This is being tested presently.

EuroNoise

Field testing of the oil pan enclosure has been successfully started. Pan enclosures will be an important part of the noise reduction package to meet the european noise regulations.

Bedplate and fuel pump drive damper drawings targeted toward the EuroNoise program are well underway and should be complete before the end of the year.

Work has been started on testing the effects of close fitting emralon coated pistons to reduce mechanical noise due to piston slap. Early testing shows the greatest noise reduction gains in light to no load conditions. The first engine has shown .5-1.5 dB reduction in 1 meter noise depending on the speed. Currently, the engine is scheduled for endurance testing after which the pistons/liner will be analyzed. If successful, driveby and additional durability testing will be started.

Current Product

----- Cylinder Head Swirl

Recent audit of production cylinder heads has indicated that a number of heads were produced (and used in production) with higher than specification swirl levels. The swirl shift did not cause NOx compliance to exceed our FEL's for the current 93 emissions product. However, the 94 product does not currently have sufficient margin to allow usage of cylinder heads with excessive swirl. This clearly indicates concern over the current process controls in the foundry and production plant. Current heads are satisfactory, but a root cause must be determined and actions taken to avoid a repeat of this condition in the future.

C Block Casting Change (Edison, EuroNoise, Thrust Brg, Thermostat, Frt End)

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Changes to the C Series engine block casting to incorporate several design

changes driven by several programs. Block casting changes include modifications for the Edison and EuroNoise programs as well as upgrades for thermostat/alternator alignment, thrust bearing support, and the front end upgrade.

FMB has completed new permanent tooling reflecting these changes. ISIR activity is underway. Other source approval activity is on-plan with engine testing underway. Introduction timing is expected to be in February. Navistar are establishing plans to modify existing tooling during the holiday shutdown. A engineering and manufacturing plan exists for expedited approval of the Navistar tooling.

#### Champion Crank Failure Investigation

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Investigation of the three crank failures on Champion graders is still underway. The root cause is believed to be a dynamic bending load imposed on the rear face of the crank by the Champion application. Efforts to identify how the load is applied and correct the situation have been only partially successful. Test data from a field visit to a problem site and a live engine rig is being analyzed. If the results are inconclusive, then dynamic crank loads will have to be measured on an actual grader.

Gear Damper Development

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The first two engines for geartrain vibration measurements have been upfitted with the necessary test/instrumentation hardware. The first engine is in the test cell. A problem with the instrumentation fixture is currently being corrected and then the baseline test will be run.

#### Marine Mount

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A trip to Charleston SC to discuss experimental test procedures and collect strain data on the modified front support for the 400 Hp Marine product was made in mid-November. The front support data was used to evaluate and finalize the 3897029 design. The drawing for this support is now in CMU drafting and is being released at "P" status by CMU0008.

The hardware needed by CMU to collect strain data in the future was discussed and the mandatory items were listed to assist getting CMU capable.

External Oiling -

The engineering release has been submitted to make the modified A pump with increased internal oiling the standard. Because of a discrepancy in the field testing, four new pumps with the drilling modifications have been ordered and will go out on field test. Our data indicates that the oil level in the fuel pump is sufficient to prevent governor wear. The question that has come up is whether there is sufficient oil to dampen some low idle surge problems that external oiling has resolved. The four pumps ordered will be going into the field in applications where this type of problem is well documented.

CDC Product Engineering Activity

~~~~~ PCR 2705 Flexplate:

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Fatigue testing continues on the glued assembly flexplate P/N 3926123. Testing is being conducted at the supplier's facility. Two test samples have been completed with the failure mode being cracks around the crank holes at 4 million cycles.



Near-net Cast Flywheel:

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D release written for near-net cast flywheel ER 931500-081. Flywheel P/N 3925872 will replace the current 3909939 flywheel. Balance study completed at supplier. New flywheels balanced within the current 9939 balance specification. Plan to write L release and schedule design review.

Edison Block:

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Residual stress work has been completed on the C Series FMB block to evaluate changes associated with the Edison program. 7 places were checked in the revised areas with no unacceptable residual stresses found. This pattern change will include several block improvements. CDC has machined 6 blocks with acceptable results. A deviation to use 300 of the pattern G castings has been issued to give CDC additional blocks for machining evaluation and assembly studies.

DSO

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930005- 6C LF670 Full-Flow & Glacier 36SE Spinner II Bypass Lube Filters

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Orders confirmed for Ford/Con-Way units. Release work to commence. Fleetguard LF670 to mount at Lube Cooler Cover Filter Head. Spinner II to be chassis mounted and procured and installed by Ford distributor. LF670 requires use of adapter unit currently released for L10 engines. Spinner II oil usage is 1 GPM at rated speed.

930006- 6C Vertical Water Filter

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Orders confirmed for Ford/Con-Way units. Investigating currently released options for acceptability.

930007- 6C Engine Mounted Davco Fuel Filter

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Orders confirmed for Ford/Ryder units. Design/release work to commence.

GENERAL

CalComp Plotter

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Purchased CalComp DrawingMaster 52436 plotter to support Pro/ENGINEER. The plotter should be received at the dock by 12/1/93.

C-Series Valve Cover

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Issued ER 931500-139 making changes to the C-Series valve cover. Changes include improvements to solve installation and interference issues and also to provide self-tapping bosses to secure BERU wiring harnesses. A 500 piece sample of covers reworked to this design were evaluated on the Assembly line with no interferences or assembly issues. Without this rework typically 3 to 5 percent of the covers experience an interference problem requiring replacement.

TRAINING

Most members of Product Engineering attended training for Product Safety Hazard Analysis given by Lee Trexler and Product Liability given by Gary Brisbin. Other training also received by some included: Classification of

Characteristics; Design Review; Failure Modes and Effects Analysis; PDCA
(Plan, Do, Check, Action); Statistical Data Gathering; Pareto Diagrams;
Cause and Effect; 2 day CPS.

S. C. Milloy

CC : DIST-CNEWS

DIST-CCPE

DIST-*C

Alyanak, E J
Bush, E E
Hager, F M
LIN, C S
Milloy, S C
Ritzline, L A
Wolff, K
Sowerby, P
SIDUR, C I
ROGERS, D G
Yager, J H
SEVAKIS, A M
GASTON, N
GOHR, L R
DOWNING, D H

Buchanan, J C
FRANZWA, R A
Johansen, G A
Marthaler, M J
Neil, S W
Virnig, D M
Klaus, J G
Doup, Doug
CORT, A
Weikert, J M
BUSCH, D A
CONLEY, J P
BEYER, M A
Hovin, L E
KOHRT, A G

More..

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Allen, W C
BEYER, S
Coggins, H F
Collie, T R
Denton-Jr, J W
Dover, R G
FISHER, K J
JOHNSON, J H
KRASZESKI, D J
LEBEGUE, J S
Long, D G
Menard, J D
PANETTIERI, R A
ROSSI, R A
UNSWORTH, J P

Alston, G
BUEL, T J
Cole, J A
Deeds, J T
Dickens, D T
Faison, K
FRANZWA, R A
Kloosterman, G C
LANG, M
Ley, C J
MARINO, T R
Murvin, E T
Richardson, L A
Stith-Farmer, M
WALKER, S G

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Queiroz, J T
Bolina, A O
Bean, S W
Yager, J H
GALE, T J
MANDT, B

PASQUOTTO, L A
Molewyk, T L
Bose, T N
Herlitz, D L
SOULTZ, B L
Barrett, P M

Ag 2-3

B

DATE: January 17, 1994
TO : DIST-C
DIST-PESEDC
FROM: S.C. Milloy
SUBJECT: C Series Dec Newsnotes

C Series
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1994 Product

All ratings with the exception of the 300Hp were successfully launched prior to Jan '94. The 300C rating was delayed due to problems experienced during the introduction process. Activity to correct the issue is nearly complete. Production (ISIR) fuel pumps have arrived at CDC. Emissions verification of two production engines with the corrected pumps will be conducted while CDC is completing the approval process.

Activity is focused on increasing production emissions data for all C ratings. Nine production engines built during December will be tested at SWRI in the next few weeks to better understand compliance levels and reduce FEL's where possible.

The low torque rating family is exhibiting higher than expected NOx levels on the limited production engines emissions tested to-date. Engineering are evaluating a change in test criteria (utilizing governed speed rather than rated) to achieve a NOx reduction. A 5 hole nozzle is also under evaluation.

Investigation and re-development has begun on the 94C 275HP automotive ratings in order to increase the margin against secondary injection at rated conditions. A sample of 10 production pumps produced 3 with insufficient margin. This seems to be caused by delivery valve and snubber valve flows both being at the high end of the specification. To date, audits of these parts indicate all are within print. Bosch has provided an injection pump with the delivery valve retraction increased from 150mm³ to 180mm³ to reduce residual line pressures. However, peak injection pressure at rated has been reduced by 80 bar with this design. Emissions results indicate a 0.007 PM penalty with the new pump along with a small NOx reduction of 0.15 Gr/BHP-hr, probably due to a dynamic timing retard. As a backup, Bosch has provided another injection pump with the LPC increased from 4.0 to 4.4mm in addition to the delivery valve change. This brings the peak pressure back to original levels but may have less secondary margin. Both of the new pumps will be evaluated for performance, emissions, and drivability. A solution must be arrived at to protect future availability of these ratings. In the meantime, Bosch is sorting delivery valves for low flow to keep supply to their plant flowing.

Transit Bus

The current 275C transit bus rating does not provide acceptable vehicle acceleration to fully meet customer requirements. The engine performance resulting from the use of #1 diesel fuel is a major contributor to the problem. A new fuel rating for transit bus engines restricted to #1 fuel ONLY has been defined. Recalibration and testing has indicated that engine response and particulates are equivalent to the baseline calibration with #2 fuel. Once the emissions verification is complete, calibration information will be provided to the field and to CDC for conversion of existing and future engines running on #1 fuel.

Futher engine response improvements have been demonstrated with a change to an exhaust manifold with a smaller flow area and B Series turbocharger. Activity is underway to complete the design/drafting work and establish rating changes to accomodate these potential imopvements.

Sketches have been submitted to the pattern-makers to shave the cores of a current high mount prototype manifold pattern to allow the testing of both an optimized manifold for the WHX40 turbo and also the WH1C turbo. Both Automotive and Industrial Performance have expressed interest in testing these configurations. If either of these tests proves beneficial, the improvement will be considered for a larger scope than the Transit Bus alone. A low mount manifold design is being drawn at BLCA under METC guidance. If the tests mentioned are successful, this design will be submitted for release immediately to fulfill the needs of the Transit Bus project. It would be followed by a redesign of other manifolds.

Edison/RP43

The C Series Edison variable timed pump development is proceeding towards an automotive production date of 1/96 and a premium industrial production date of 6/96. January milestones include freezing of the injection pump design and initiating design integration with Ford and Case.

Conceptual work for the RP43 fuel pump is now complete. Bosch has agreed to add additional bosses to the pump and to remove material from the bottom of the pump to accomodate air compressors. A ductile iron gear housing is being developed for this application. Discussion is on-going as to the merits of pursuing a grid heater vs a flame-start for cold start.

Work is focusing on providing design and performance releases for concept prototype builds. A total of seven concept engines will be built in the April thru July time frame. Three engines will begin dynamometer reliability testing. The remaining four engines are slated for field test.

Industrial Emissions

Development of the 6CTA (JWAC) #1 curve is nearing completion. The target Hp of 260@2200//275@2000rpm will be successfully achieved. Fuel system hydraulics have hampered attempts to maintain peak torque within thermal limits. Utilizing the boost control to raise the speed at which peak torque occurs has been demonstrated to resolve the issue (1700rpm peak torque). This solution is under review with the marketing groups. Cold testing is scheduled for early February.

New fuel lines have been fit-checked on the engine for the 260 HP CTA. These lines will be sourced in the new HS-10 material. New AFC lines have been designed and have been sent to CDC for fit-check. New FF lines have been designed and are being prototyped for the P7100. Current design effort is heavily devoted to the design of a grid heater as some industrial customers are reluctant to use ether to cold-start. This heater is not to be used as a white smoke control. Work is on-going to define turbo options.

The current 6CT intermittant rating development has met power, smoke, and emissions targets, however, BSFC still exceeds target. Testing of the Holset 'EWM', Exhaust Wastegate Management, turbine casing did not yield any performance improvements. Increasing the wastegate opening port did result in limited success. Results are being verified. Work is focusing on reducing the exhaust manifold cross-sectional flow area as a potential to improve BSFC by reducing flow losses.

CT fuel lines have been designed and are being prototyped. AFC lines are being

designed and prototyped. Turbo options are also being developed. A grid heater set-up will be required for this engine also. The grid heater has an impact on fuel lines and AFC lines.

EuroNoise

Field test plans for the EuroNoise engine in the UK are being finalized. DEP builds should take place during early March.

Development activity for the fuel pump drive damper is on-going. Baseline gear train vibration data has been obtained on an '88 automotive rating and has demonstrated a viable measurement technique. Currently a '91 rating is being tested with the '94 and several damper options to follow.

A design for a higher inertia fuel pump gear has been developed. Investigation is on-going as to the feasibility of adding even more inertia to the gear. A design for the damped oil pan has also been submitted to Stress. A bedplate design was also completed and work is on-going with Fel-Pro to develop a proper gasket.

Current Product Support

Competitive pressures due to a soon to be released 400Hp CAT 3116 Marine product have resulted in discussions regarding a 5% uprate to the current 400C. The lighter CAT 3116 product will outperform the C Series unless this uprate is achieved. Discussions with the Marine group on this program (labelled 'Sprint') have yielded initial plans to increase Hp to 420 and resolve as many product issues as possible prior to a mid-March introduction for '93 boat models. Base engine product changes include a change in injector nozzle hole size to increase hydraulic flow and a turbocharger change to improve transient response. The intent is to avoid a fuel pump specifications change if at all possible.

Many production issues exist and details to resolve and under discussion.

A meeting between Champion and Cummins to discuss the C crank failures in Champion road graders occurred on December 14. Data from Champion, Cummins, and a joint field investigation was reviewed and a previous 7-step process on this issue was revisited. The group modified the 4th step test program, and this work is underway.

Design/Drafting Integration

As a part of the plan to improve the communication and our design/drafting effectiveness, METC has reorganized the seating arrangement within the design and drafting areas. The moves were completed over the Christmas holiday. B and C designers are now integrated with the drafting group. There have been no changes regarding reporting relationships. The group has defined project oriented responsibilities to help further improve communication and effectiveness.

CDC Emissions Test Cell Correlation

.Correlation tests were completed on 2 SEA engines that had been tested at CTC. Correlation was good when considering the differences in fuels. We will be running a Gauge Repeatability and Reproducibility check on the Emissions Test Cells, under the direction of the CDC Quality Control Group.

.We are scheduled to get the Corporate Round Robin emissions correlation engine

in mid-January. This engine (a 6C8.3-250) received its first check at CTC.

CNG Test Capability

.CNG supply lines are being run into Test Cell 3, in preparation for our support for the natural gas program.

Cam Welch Plug

A design review was held to look at several proposals for improving the cam welch plug seal. One design being reviewed includes the addition of an oring with the current welch plug and minor changes to the block. Intial testing has begun with engine testing expected in Februrary.

S. C. Milloy

CC : DIST-CNEWS

S.J. Davidson

DIST-*C

Alyanak, E J
Bush, E E
Hager, F M
LIN, C S
Milloy, S C
Ritzline, L A
Wolff, K
Sowerby, P
SIDUR, C I
ROGERS, D G
Yager, J H
SEVAKIS, A M
GASTON, N
GOHR, L R
DOWNING, D H

Buchanan, J C
FRANZWA, R A
Johansen, G A
Marthaler, M J
Neil, S W
Virnig, D M
Klaus, J G
Doup, Doug
CORT, A
Weikert, J M
BUSCH, D A
CONLEY, J P
BEYER, M A
Hovin, L E
KOHRT, A G

More..

DIST-*PESEDC

Allen, W C
BEYER, S
Coggins, H F
Collie, T R
Denton-Jr, J W
Dover, R G
FISHER, K J
JOHNSON, J H
KRASZESKI, D J
LEBEGUE, J S
Long, D G
Menard, J D
PANETTIERI, R A
ROSSI, R A
UNSWORTH, J P

Alston, G
BUEL, T J
Cole, J A
Deeds, J T
Dickens, D T
Faison, K
FRANZWA, R A
Kloosterman, G C
LANG, M
Ley, C J
MARINO, T R
Murvin, E T
Richardson, L A
Stith-Farmer, M
WALKER, S G

More..

DATE: February 7, 1994
TO : DIST-C
DIST-PESEDC
FROM: S.C. Milloy
SUBJECT: C Series January Newsnotes

1994 Product

Emissions results of 94C 210 and 225 BHP ISIR engines indicate higher than expected NOx. Based on this, a change was implemented retarding fuel pump static timing from 11.0 to 10.5 deg BTDC. In addition, the emissions test rated speed has been changed with the EPA from 2200rpm to 2400rpm. The above two changes are expected to reduce NOx by 0.55 Gr/BHP-hr. Since that time, a production audit emissions test of a 210 HP engine gave results of 4.73 NOx, which is close to design level. Work is continuing to determine if there is an assignable cause for the elevated NOx on the ISIRs.

Three 250 low torque rise 94C engines were emissions audit tested at SwRI with the average emissions of 4.95 NOx/0.084 PM for cold/hot. This limited data indicates very good compliance with our FEL.

Fuel maps have now been published for all 1994 C-Series automotive CPLs. Data files have been provided to CTC for customer support through VMS.

All 94 releases still needed to support the 1994 introduction are being given highest priority. These releases are primarily related to the Bluebird introduction later in the first quarter.

Endurance testing of the Beru flame start system yielded very encouraging results with the production plugs from Beru's Tralee facility. Testing is continuing on a design change which is expected to improve plug life by an additional 50%. CEL is experiencing capacity difficulties in supporting the control module production for the 12 and 24 volt Beru products as well as the B Series grid heater. Additional resources are being applied to increase capacity to 210 units/wk which will meet the short term needs.

Transit Bus

Poor acceleration has been a significant issue for the C transit product. Two major activities are underway in order to improve the transient response while maintaining the stricter emissions compliance (.07 g/bhp-hr PM).

- Release of special FR for #1 diesel fuel only
- Development of new manifold and turbo to improve low end response

A fuel pump recalibrated for use with #1 fuel was sent for field evaluation at COTA. Test results indicated that the pump improved vehicle response to an acceptable level. Emissions verification for the recalibrated pump resulted in the same levels as the #2 fuel pump rating. The new fuel pump rating for #1 fuel will be released and treated as a derivative pump due to the relatively low volumes forecast for '94.

The rubbed cores for the experimental manifolds for the transit bus have been completed. The parts should be available at METC by March 15. Testing is to be completed by March 31. At this point, a go/no-go decision will be made. Drafting lay-out of the manifold and WH1-C (B size turbo) is complete. The manifold will be released immediately after performance verification testing.

Edison/RP43

Edison controls optimization continues to progress on bench and in the Ford L8000 tractor. Initial testing of the CM520 module on the tractor has been very successful. It appears that the CM520 ECM with its improved throughput and rack resolution has been the big improvement over the CM400 used in initial tests. Throttle response is also improved. This work has been continuing with the RE30 governed P7100 in anticipation of the RP43 arrival. The CEL controls group are to be commended for their outstanding work.

Other controls work has centered around design reviews relating to the start of injection (SOI) governor and timing control architecture, 4D timing control strategies. Strategies/software/hardware are being reviewed for intent to standardize with Celec wherever practical/possible.

Design activity to support the Bosch RP43 fuel pump drive and mounting will be completed in the next few weeks. Procurement of prototype hardware for April dyno and field test engines has been initiated. The design of the ductile iron gear housing currently expected to be required for the RP43 will be completed before the end of February. Recent cost quotes indicating that the housing will add approx \$120 to the overall engine cost make clear documentation of the need for ductile iron critical.

EuroNoise

Initial design work for EuroNoise components has been completed. Design Reviews are scheduled to be completed by Mar 1. DR's will be scheduled so that both DEP and CDC will be able to participate. To support testing at METC as well as field tests, 30 sets of hardware will be ordered.

Currently, the EuroNoise program consists of the following components:

1. Pan Enclosure
2. Bed plate
3. Large inertia fuel pump gear
4. Close Fit Pistons
5. Double wall front cover

Prototype testing completed to date both in test cell and on field test has been successful. Four field tests currently running with oil pan enclosures have logged 44,000 miles total since first of Oct. While no problems have been recorded, enclosures will be inspected during next few months to ensure no problems exist.

Front end noise has been identified as a major noise contributor for all 'P' pump applications. All baseline geartrain vibration data has been collected. Data collection for the '94 EPA/EuroII rating is in progress. Initial results from the '91 baseline indicate that a threshold inertia level exists that reduces torsional geartrain activity. Increases in inertia provide no added benefit. Noise verification of the vibration data is underway to determine the optimum inertia levels. Effects of the inertia on the Bosch P7100 fuel pump will need to be quantified once an inertia value is finalized.

Current emphasis is being placed on procuring parts for durability testing both at METC and on field test.

Off-Highway Emissions

Evaluation of the Bosch P3000/RSV with 12mm diameter plunger was completed in January. Expected improvements in low speed performance did not materialize. Final documentation of the 11mm plunger design and tolerance sensitivity is underway in preparation for delivery of the 260Hp 6CTA FAP.

Emissions sensitivity testing of the 6CT has indicated that a 1 degree advance in static timing can be achieved while still maintaining adequate margin for NOx compliance.

Design work on a grid heater design for the 6CTA is complete and samples have been ordered from Phillips-Temro. Two separate options for fuel lines and aftercooler water lines will be required due to the height increase imposed by the grid heater spacer. This was not unexpected and work is on-going to support the need for plumbing compatible with the grid heater. D releases are being written. Support work for prototype installations is on-going.

Current Product Support

A rash of 32 Bosch A-pump shaft failures has occurred within the last 40 days. All of the failures were associated with sub-zero weather conditions and the majority are high speed (2500rpm) ratings. An investigation to understand the cause was initiated immediately and continues as a top priority. A trip to measure crankshaft torsionals and fuel pump shaft strains on a problem unit is scheduled. The effect of cold ambient on damper performance and sensitivity of the pump shaft to the gear drive material modulus will be evaluated. Short term action to limit the number of occurrences has been taken.

The first batch of 300 production C series blocks from FMB's new pattern G tooling were machined and used at CDC this month. The new pattern contains the latest changes including MRE holes, Thermostat/alternator support alignment pad, thrust bearing retainment ridge, etc. No machining or assembly issues were documented with the new pattern.

Lift pump spring failures continue to occur without resolution. Failure mode is beakage of the inner spring due to contact (fretting) where it contacts the outer spring. AC Rochester has not responded regarding these failures. Efforts will be made to get proper failure analysis and corrective action feedback from AC.

Four pumps with increased internal oiling capability were delivered this month from Bosch. These 'A' pumps will be used to verify the improved internal oil design will successfully eliminate low idle, low speed surge in problem installations. These installations are currently fixed by external oil.

Several field reports of valves and collets receding into the valve retainer causing progressive damage have been recieved. Step 1 of the problem solving process is currently on-going. The Cummins-Ford infant care team is compiling the operating conditions which existing at the time of each failure. Failures appear to be related to engine overspeed based on driver comments. Metallurgical examinations on failed hardware indicate that the parts meet the material specifications. Retainers have been modeled on Ansys and photostressed to determine their deformed shaft and the location of maximum stress. Operating strains are in the process of being measured under normal and overspeed conditions to determine highest load conditions. Discussions are underway with the supplier regarding potential changes and their cost and leadtime impact.

Marine Support

Marine Sprint program - With METC support, Cummins Marine has nearly

completed development and calibration of a 420BHP at 2600 rpm product as an uprate of today's 400M. Performance data to date indicates acceptable smoke and temperature levels. Nozzle tip temps are yet to be measured but are not expected to be over limits.

The Marine Uprate/Resource program is currently wrapping up the product profile and beginning to develop the performance recipe required to meet the profile. To meet a MidRange strategy of replacing Nippondenso fuel pumps with Bosch, all marine ratings will be replaced with Bosch P7100 fuel pumps. Currently the Lead rating would be a 440 Hp high output @2600 rpm. It would be followed with a 400 intermittent and a 350 medium duty engine, all sea water aftercooled. A recent request to increase the pleasure boat rating to 465Hp has been received. This request is under review.

CDC Emissions Test Cells

.Ten of the DOE/EOL engines have been line set. Pre run-in steady state emissions have been run on 6 of the engines and post run-in SS emissions have been run on 2 of them. No transients have been run on any of the engines. Oil consumption, TEOM sampling of the raw exhaust, and Bosch smoke are also being monitored. Round robin and audit work have taken priority over the DOE/EOL tests.

.The round robin emissions correlation engine is now in an emissions cell for correlation work. It had previously been run in the Certification cell (201 & 301) at CTC. We have been getting very repeatable data but the NOx values had been high compared to CTC. We added a heat exchanger to warm the chilled water to the Charge Air Cooler (CAC) and it brought the NOx values to the level obtained at CTC. System is being tweaked and the correlation testing proceeding.

.Self audit testing of a 6B-230 also resulted higher than expected NOx values. The engine was shipped to SWRI for a check on the emissions data. A 6B-210 audit engine was run-in at T/C 1. It is scheduled to be emissions tested, awaiting the results of work improve our NOx measurements.

.We are using the METC designed oil consumption rigs on a routine basis for all our run-ins. The oil consumption on the latest DOE engine now being broken in at T/C 1 shows stable oil consumption after about 20 hours.

CDC Product Engineering

Ralph Nelson has been promoted to Assistant Chief Product Engineer of the CDC Product Engineering organization. Additionally, Ralph will fill the role of Product Leader of the performance group replacing Chris Ley who is moving to METC in March. Ralph will serve as primary backup to Jim working to continue to develop the capabilities of Product Engineering. Ralph's activities will initially focus on conducting emissions self-audits, projecting compliance levels, and resolving emissions issues as they occur.

Jeff Lebeque has accepted the position of Product Leader in the Mechanical Development area during an interim period while Sherm Beyer is acting CPE at Telco.

Brian Stone joined CDC Product Engineering in Dec '93. Brian will have the responsibility for performance development of the natural gas program and reports to Ralph Nelson.

Improvement Activity

METC completed training of all employees on the Common Approach to Continuous

Improvement. Activities are now focussed on beginning improvement projects in order to provide OJT in applying the principles discussed. Some projects are already in-progress with one project (Building C area) complete.

A better method to collect data from rotating assemblies has been designed as the result of Dave Ebert's vision for an improved process. Dave and Jean-Pat Rich initiated a new design concept for getting strain signals through slip rings with less noise and frustration. The design concept was discussed and reviewed in meetings between the stress and instrumentation engineers and technicians. The result was a design that is expected to save time and reduce electrical noise.

S. C. Milloy

CC : DIST-CNEWS

S.J. Davidson

DIST-*C

Alyanak, E J
Bush, E E
Hager, F M
LIN, C S
Milloy, S C
Ritzline, L A
Wolff, K
Sowerby, P
SIDUR, C I
ROGERS, D G
Yager, J H
SEVAKIS, A M
GASTON, N
GOHR, L R
DOWNING, D H

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More..

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More..

DIST-*CNEWS

Queiroz, J T

PASQUOTTO, L A

pg3 9

DATE: March 14, 1994
TO : DIST-C
FROM: S.C. Milloy (SEAN)
SUBJECT: C Series Febuary Newsnotes

1994 Product Introduction

The C300 rating was launched in Febuary. This was accomplished by the ordering of production fuel pumps in parallel with ISIR. Testing of ISIR product indicated that improper setting of the fuel pump boost control resulted in poor low speed drivability performance. The necessary corrections have been identified and actions are in place at CDC, Bosch, and OEM's.

Investigations are on-going regarding the 210/225 NOx compliance. High speed data acquisition is currently being run on the C210 and C225 ISIR engines to determine the difference between low and high NOx engines. Specific areas of interest includes dynamic timing as it may be affected by the low pressure system variations.

Combustion documentation of the 94C ratings has been nearly completed. One outstanding issue remaining is the effect of cooled vs. uncooled cylinder pressure transducers on the heat release curves, especially at light load. This work will be ongoing as it is critical for use as a baseline to compare Edison and Encore fuel systems and engines.

Beru has submitted samples of the new 5 mm longer 12 and 24 volt plugs. The 12 volt plugs have been approved and testing has begun on the 24 volt. If successful, the new design will be released within three weeks. Air compressor options have been raised to P status upon completion of a P release by Holset. Turbo drain tubes for Bluebird have been released and prototype parts are at CDC to support initial builds.

Approval of the C45PbK-ECM injector nozzle holders from Turkey has been completed.

Transit Bus

Activities have focused on improvements in transient response for the 93 and 94 transit bus product. Two specific projects are underway:

- Release of special #1 diesel fuel rating
- Low speed performance enhancements with manifold and turbo optimization

The #1 fuel calibration work has been completed at METC and certification issues have been addressed.

Performance efforts are underway to determine the fuel system requirements for a higher response 94 transit bus rating with a smaller flow area exhaust manifold and smaller turbocharger. Currently mapping performance to ensure adequate secondary injection margins and altitude capability for the various ratings.

The design for the exhaust manifold was completed and turbo plumbing work is on-going at this time. Prototype parts are due in two weeks and results from testing are expected by the end of March.

Edison/RP43

Designs are complete for all required components and prototypes on order to

support the concept reliability and performance testing. Bosch are expected to deliver the first RP43 pumps in March, however, these pumps will not feature the pump housing casting/machining required for the C Series. Pumps with production intent features will not be available until May.

There are two major design related issues pending:

1. Possible requirement for ductile iron gear housing at considerable on-cost.
2. Selection of sensor for engine speed and timing information.

A ductile iron gear housing may be required to support the RP43. The RP43 is 20% heavier (56lbs) than the P7100 increasing gear housing stresses and leak potential. Additionally, Bosch require pump acceleration limits that are significantly lower than the P7100 due to electronic governor reliability issues. These two factors will make it very difficult to obtain a satisfactory aluminum gear housing. Design optimization and in-depth structural analysis will begin comparing the aluminum and ductile designs once production intent pumps are available.

A Hall Affect speed and timing sensor has been proposed as the appropriate selection for the Edison program. The Hall Affect sensor is desired as it is capable to support static and dynamic timing. Although commonly used on gasoline automotive products, there is no previous experience on diesel engines. Accelerated efforts are required to understand the potential reliability risks.

Edison engine testing has been delayed with the CM520 due to software delays. Further dyno and vehicle testing are waiting on the new software. Performance work continues on the prototype engine running at CTC. This work has been focused recently on the mapping of the fuel system in terms of fuel delivery vs. LPC and rack position. Other controls related parameters are also being characterized. Additionally, steady-state smoke and NOx mapping has been ongoing in order to determine best tradeoffs.

EuroNoise -----

Design reviews of pan enclosure, bedplate assembly, pistons, side shields have been completed at Darlington with good cross functional attendance. Final 'D' phase design reviews will be conducted at METC with CDC participation during early March.

Initial driveby testing of both a baseline and the "quiet" engine sent to DEP Tech Ops has been completed. Additional testing such as source id, truck treatment, etc. is ongoing and data should be forth coming in a few weeks.

The close fit Emralon piston test completed the first 500 hour HOT BOX test with no major concerns. The engine has been rebuilt with new rings and liner using the same pistons to accumulate an additional 500 hours under Hot Box conditions. These pistons are now approved for field trial evaluation.

Field testing of the bonded oil pan enclosure has achieved 100k miles (2300 hours) to date on 5 units with no issues identified.

The design work has been completed for the front sump oil pan. Other oil pan enclosures will be worked out after the initial one is tested to verify the design. The other components have been sketched and will be D released with drawings.

Gear train noise/vibration:

Analysis is still underway of the '88 and '91 baseline data taken earlier this year. Work is being done to compare this data with recent noise data

taken with the same increased inertia. Instrumentation problems and a lack of data acquisition equipment forced a delay in the measurement of the '94 data. Vibration testing is scheduled to begin again March 1, followed by measurement of P7100 shaft strains with the increased inertia.

Off-Highway Emissions

A customer request for a grid heater has been incorporated into the industrial emissions program. Recent applications feedback after the original concept design was accepted indicates that the increased overall engine height to accommodate the grid heater is unacceptable. Further design reviews are planned to reinvestigate the customer impact. This latest feedback jeopardizes Dec 94 availability of this option.

The new FEAD design is being sought by automotive customers in advance of the proposed introduction date. A schedule has been developed for the componentry which would allow it to be available in January of 1995.

Piston templug testing on the 300 HP combine rating has been completed. Templugs have been sent to AVL for analysis.

Current Product Support

A significant number of Bosch 'A' pump shaft failures (bending fatigue) have occurred during this past winter. The following information exists:

- All failures have been experienced in very cold ambient climates.
- Engines built since July '93 are affected.
- A large population of pre-July '93 engines survived the winter w/o incident.
- Majority but not all failures have occurred on high speed (2500rpm) ratings.
- 80% of failures have occurred on Champion applications.

A trip to measure fuel pump shaft strains and crankshaft torsionals was conducted in February. Measurements were conducted on a Champion road grader with ambient temperatures ranging from -20F to 0 F.

Tests were run with two different fuel pump gear materials, low and high speed rubber dampers, and a viscous damper. Test results indicate excessive torsional vibration with both rubber dampers in subzero conditions. Fuel pump shaft strains were found to be linked to torsional activity and were also excessive with both rubber dampers in the subzero environment. The viscous damper significantly reduced torsional vibration levels and fuel pump shaft loads under the same conditions. Changing the fuel pump gear material from steel to ductile iron did not significantly reduce pump shaft strains under cold rubber damper conditions. Discussions are now underway to determine the appropriate short and long term actions.

Investigations continue to determine what changes in engine or applications are contributing to the failure. Although ambient conditions are improving, this issue needs to be resolved as soon as possible.

Investigation into valve retainer failures indicate that the problem is a secondary failure mode resulting from other component failures. Participation in a Ford failed engine teardown at the Louisville Distributor and failure data from the Ford Infant Care Team reveal the retainer failures may be secondary. All of the engines suffering from retainer relaxation have experienced other major component failures (oil in the intake, engine runaway, spun cam gears, repetitive turbo failures....).

Valve retainer operating loads under operating conditions up to 150% rated speed are being measured to better understand the root cause and retainer robustness.

October SEA Update:

Oil consumption testing on the high lube SOF experienced on last year's SEA testing has been completed. The results show the valve stem seals to be the culprit. Emissions verification testing is planned. Also, work with the seal supplier (Perfect Circle) has begun to identify differences between good and poor performing seals of the same part number.

Oil carryover reduction:

The latest breather design tested has demonstrated very good results. Oil carryover was measured at 2 oz/100 hours. This compares to the baseline condition of 56 oz/100 hours. The next steps are to verify this design on a second set of hardware. A screw on adaptation of a breather used on a V903 engine will also be tested as a possible fix for customers who are currently experiencing a problem in the field.

Front end upgrade:

Tooling for the front cover for the new front end is proceeding on schedule. This is currently the pacing item on the front end implementation.

Encore

Jim Kahlenbeck joined the C Series engineering team as Director of the C Engine engine development. Jim is currently establishing component systems teams to complete the current concept definition work and begin detailed design and analysis targeting an August C1 build schedule.

A preliminary analysis of the C connecting rod was performed to determine margin with regard to piston mass (articulated piston), rated speed and increased cylinder pressure. The analysis indicated that the rod shank design and bolted joint would require changes if these parameters are significantly increased.

Transeng analysis has begun utilizing initial estimates of the C intake port and several proposed camshaft lift schedules.

The work on the overhead has been started and preliminary designs for the rocker levers are available.

Training

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Lee Ritzline, Lisa Gohr, and Jean-Pat Rich completed photostress training during the month of February. 75% of the C stress department is now trained in this technique.

S. C. Milloy (SEAN)

DIST-\*C

Alyanak, E J  
Bush, E E

Buchanan, J C  
FRANZWA, R A

DATE: June 16, 1994  
TO : Ms. S.J. Davidson  
DIST-C  
DIST-6880126  
DIST-CCPE  
FROM: S.C. Milloy (SEAN)  
SUBJECT: C Series May Newsnotes

C Series

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#### 1994 Automotive/FEL Reductions

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94C FEL Reductions - Based on recent analysis of 94C emissions self-audit data, the NOx Family Emissions Limit (FEL) for emisisions family 413G has been lowered from 5.1 to the EPA standard of 5.0 Gr/BHP-hr. This family includes the 210/225/250LTR ratings. This change means that critical NOx credits are no longer being consumed by this high-volume family of rtgs. The audit data indicates at least 90% compliance to the 5.0 standard.

Testing was also conducted to determine ways of reducing the NOx FEL on family 413F (275/275/250HTR), which is currently at 5.2 Gr/BHP-hr. Of the three ratings, only the 275@1800 is causing the need for the higher FEL, due to its low rated speed. The testing conducted was to evaluate the effect of changing the EPA emissions test rated speed from 2000 to 2100rpm. Results of the test indicate that increasing the EPA rated speed to 2100 would lower NOx by 0.15 Gr/BHP-hr with a slight PM increase. This change is being pursued.

Testing was also completed with the 5-hole nozzle on the remaining 94C ratings. The data indicates that the change to the 5-hole nozzle could be made across the board for the 94C automotive product. On average, the NOx emissions are reduced by 0.3 Gr/BHP-hr, with PM either no affected or even slightly reduced on some ratings. ISIR for the new injectors is scheduled for the first week of July.

Oil consumption development continued with pistons with an increased cutback over previous designs and increased mid ring gap over the current mid ring. Rated oil consumption was measured at 38 grams/hr and 10 grams per hour at mode 5. The engine is currently waiting on emissions testing. The pistons from this engine had the second ring land cut back from a previous test in which rated oil consumption was measured at 60 grams/hr. Particulate emissions from the earlier test were 0.097 catalyst out and .127 engine out.

The first C Series engine with a 10 mm top ring location was tested at METC. This development is being pursued to improve white smoke and transient response. No improvements in low speed smoke were observed when run by the performance group. Oil consumption also measured at 60 to 65 grams/hr. After this, the engine completed at 250 hour hot box test without incident. The engine has yet to be torn down for evaluation.

#### Edison

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Activity to support build of CV level performance, reliability, and field engines continues on-plan. Work toward a CV field test calibration is progressing. Injection timing schedules have been developed with further refinement anticipated. METC and the CEL systems/controls team have recently finished review of all calibration parameters and established which group is responsible for each parameter.

Delivery of 7 CV RP43 samples with sandcast pump housings were recieved.



Structural testing to determine the need for a ductile iron gear housing (+\$80 cost) is underway. The increased size and weight of the RP43 as compared to the P7100 fuel pump has driven the ductile iron gear housing question.

The fuel temperature sensor location has been decided. The sensor will be mounted in the fuel pump. Discussion with Bosch is on-going as to whether the sensor could be mounted before the pumps arrive at CDC in production. Design work has been completed on the ductile gear housing and the first sample was poured. Greater than expected shrinkage occurred and the production pattern will have allowances built in for the new shrink rate. The prototype pattern is being corrected and parts are to be completed and sent to CDC for the upcoming June build. Preliminary work on the design of the Hall effect sensor was completed and the new sensor body will be 30 mm long. If the existing BLX sensor tooling can be modified slightly, prototype parts could be available to begin testing on DV engines later this fall.

#### EuroNoise

Three US field test engines have been successfully built at CDC giving them opportunity to review the design. While the bedplate, etc were installed off line, many at the plant were able to review its potential effect on the line. Issues learned from these builds have been used to improve the design for the UK builds.

Durability testing of the bedplate, bedplate and oil pan gaskets, pan enclosures, and coated (Emralon) tighter fitting pistons continue without incident. Additional testing will begin in the near future as all components have been incorporated into the Edison CV test builds.

Testing of Emralon coated pistons is continuing as 3 field test engines were built at CDC. The pistons appear to be working well in engines to date, however, coating quality will be a serious concern. One batch of pistons had failed when the coating had come off in the wash tank prior to engine test. This failure was attributed to improper curing of the coating.

To optimize the load balance on the EMR gasket, work is being done with the supplier to study the effect of seal height on sealing in the two joints where gasket will be used..between block and bedplate and between bedplate and pan.

Drafting work on the bedplate, pan enclosure, gaskets, etc. is near completion. Layout requests have been submitted for std center sump enclosure while enclosures for other pan designs are being investigated by the NPIT and PCR groups.

Noise testing continues both here and at Walesboro to both qualify the new designs and investigate future noise reduction potential opportunities. To support the commitment to reducing the noise levels of the C engine additional work is beginning at Ricardo-UK and AVL to study and rank the various forcing functions which emit noise from the engine. The study will include but is not limited to;

1. Combustion noise impact on overall noise
2. Piston slap effect on overall noise
3. Gear train dynamics effect on overall noise
4. Engine torsionals effect on overall noise

Results of this study should lead to additional noise reductions through structure optimization rather than adding covers to the engine.

#### C Series Elite Program

Heat rejection remains the most significant issue regarding the 6CTA

emissionized industrial product. Increases in intake air flow has resulted in a significant increase in heat rejection to the aftercooler. Boost pressure has increased due to the addition of wastegating to improve low speed performance. Attempts to reduce boost for the 250 and 260 Hp ratings has led to other performance issues. Alternatives including a RQVK governor are under investigation. Heat rejection for ratings 240Hp do not exhibit the aftercooler increased heat rejection and will meet the product profile deliverable.

Performance testing of a reduced crossection exhaust manifold on the 6CT product has resulted in a 25ft-lb (5%) improvement in low speed torque at the same smoke level.

The optimized exhaust manifolds were tested by Performance. The HX40 version was found to produce the greater benefit and this concept will be developed into a final design. Fuel lines have been completed as well as AFC and turbo plumbing. New air compressor plumbing was designed to accomodate the new block to be introduced in early 1995. The current grid heater design has been found to have insufficient clearance to comfortably remove the injectors for service. New concepts are being explored which will require flow testing to be verified.

#### Encore

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Encore program functional reviews and contract review were held during the month of May. Key contract changes included continuing development of an increased displacement (9L) engine for the C Series. The need for increased drafting resources above AOP was recognized and this issue is being worked. A primary C issue is the backward compatability of the cylinder block. Modifications to the 2 valve cyl head casting will allow a common Encore block and head gasket for both 2 and 4 valve product.

May manpower support for the C program had a slight improvement over April. Exempt support was at 6.5 man-months and Hourly at 1.1. Exempt support was 1 short of forecast and hourly was 1.5 short. June should see a growth in both areas.

Details of the C1C engine continue to be tracked. At this time the major issue stems from delays in the Block tooling. Currently, we are a minimum 3 weeks behind schedule. We still plan to build and test the first C1 on time.

We introduced the reliability team during the past month and continue to have active meetings with the current teams. The fuel system, performance, and accessory teams are next to be kicked off.

An FE model of the current 2 valve head has been developed in an effort to better understand valve seat drop-out that is experienced on our most severe abuse tests and has been observed on the Marine product. Next steps will be to model the 4 valve head and apply this experience to the new design.

Simulation and analytical studies of the C Series overhead design indicate that the current push tube proposal with 10mm ball should provide for adequate stability and overspeed protection.

#### 94 Transit Bus

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Testing has been ongoing for the release of a 1994 transit bus rating with reponse levels higher than today's product. The testing has centered around revision to injection pump and air handling recipes. After analysis of the comparison data, it has been decided to keep the same FIE recipe and not release a new system. The new system was eliminated due to insufficient margin against secondary injections.

The last step of the development is to evaluate a new reduced volume exhaust manifold and a new turbocharger. Both the manifold and the turbo have been seen to improve low speed air/fuel ratios and reduce smoke. Several turbo recipes in addition to one developed in APD are being evaluated for response, emissions, BSFC, and altitude capability. The last leg of the testing is the transient emissions verification, slated to begin June 9th and last approx 2 weeks. A concern is the duty cycle of the transit bus application, and what it means to turbo compressor low cycle fatigue with the more responsive turbo. This will be reviewed carefully with Holset and METC mechanical development.

#### Current Product Support

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Work is progressing on the new breather design. The new design requires a new valve cover as well as new fittings and tubing. Testing of the new breather design are ongoing. Oil carryover was reduced on one engine running on cycle 6 from 16 oz/hr to 0.56 hz/hr. Field results from one engine are also encouraging. 45 units are now available for field upfit and further testing, with 30 more units on order. 10 units have also been shipped to DEP for evaluation.

FEA modelling on RASNA is proceeding to determine the effect of changes on the engine mounts to accomodate the use of the viscous damper. This is a new venture for Design to move into FEA modelling. Thus far the seamless interface between Pro-E and RASNA has worked very well.

Source approval testing of KSP pistons has begun with a piston marking test. Oil consumption was measured at 50 grams/hr. The engine is now waiting on emissions testing.

A powder metal hydraulic pump adapter failed engine test. sending the design has been sent back to the drawing board. This part represented a \$13/engine cost reduction.

The first source approval test of a high speed Holset damper has been completed. The second test is scheduled to be run at Holset, Mexico and is expected to begin in June.

Work is progressing toward the development of a new intake port swirl specification to be used with the new Tippleman flow bench. Data has been generated on the Tippleman bench in Jamestown in anticipation of arrival of the METC bench at the end of this month. To date, the data indicates that 3.0 swirl on the current METC bench equates to 3.0 on the Tippleman, but that the Tippleman might show more approximately 4.0 for a 3.6 measured at METC. Emissions tests will verify that the new specification is emissions robust.

#### CDC Product Engineering

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We have audited about 20 engines since the first audit on 3/31. Those have been about 1/3 C Series product.

The first of the 16 Design of Experiments engines has been completed. Engines are being sent to ETS for breakin and oil consumption data.

We are now getting emissions certification fuel directly from Phillips from the same lot that CTC and METC use (S-252).

The Quality Lab has received a Gas Chromatograph (GC) used in determining the fuel/lube ratio of the Soluable Organic Fraction of exhaust particulates. Turn around time will be reduced as this extractant is now sent to CTC.

The Quality Lab also has received a GC for analyzing the non methane hydrocarbons as would be monitored in CNG emissions testing.

The Skilled Trades Programs for Instrumentation and Mechanical Technicians has been approved by the State of North Carolina.

Natural Gas (B Emerald)  
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Since the last update, only 2 new engines have been built due to a shortage of prototype parts supplied by CTC. The next planned builds are for 5 engines split between 6/6 and 6/9. These engines will be the first full batch to go to Customers for market seed/field test instead of being engineering engines.

From data obtained during several 20 hr. tests run here on engines in test cell 10, CTC engineering has discovered and corrected several problems with the engine control system. The test plan for future engine builds is to run them all on a 25 minute test before shipping unless unforeseen problems dictate a 20 hour test.

Customer satisfaction with the current field test engines is high with comments that they preferred driving it over the same vehicle with our diesel engine in it. The only major customer complaint to date concerns oil consumption since the current average oil consumption among the various field test buses is 1qt/300 miles. This problem is greatest in vehicles that spend alot of time at idle or go through alot of full throttle-to-closed throttle decelerations since this is the time when intake vacuum is greatest. New intake valve stem seals as well as tighter piston clearances are currently being investigated in Columbus.

A great deal of work has taken place at CDC over the past month concerning subassembly workstation setup and completion of process FMEA's for the sub-assemblies. The gas engine is currently on schedule to become the first off line sub-assembly to utilize error-proof tooling.

CDC Product Engineering continues to support efforts in Columbus by helping to decipher new shop orders as they come in and work with applications engineering to come up with workable orders. Work also continues on options proliferation and determining compability of current diesel options with the gas engine.

S. C. Milloy (SEAN)

DIST-\*C

|                |               |
|----------------|---------------|
| Buchanan, J C  | Bush, E E     |
| FRANZWA, R A   | Hager, F M    |
| Johansen, G A  | LIN, C S      |
| Marthaler, M J | Milloy, S C   |
| Neil, S W      | Ritzline, L A |
| Virnig, D M    | Wolff, K      |
| Klaus, J G     | Sowerby, P    |
| Doup, Doug     | SIDUR, C I    |
| CORT, A        | ROGERS, D G   |

DATE: July 28, 1994

TO : DIST-JPJ-NEWS

FROM: S.C. Milloy (SEAN)

\By: S.J. Davidson

SUBJECT: MR Engineering Newsnotes - June

B SERIES

=====

#### Current Automotive B

-----

Testing continued to solve the altitude issue with new 2.5 LPC 160 HP pump. Increasing the line size from the fuel tank to 5/16 to 3/8" ID reduced fuel restriction to a level which solved the loss of power. This solution is accepted by Chrysler, but will take approx 26 weeks to implement. Other near term solutions such as increased overflow valve pressure from 1.5 to 2.5 bar and reduced fuel return orifice were not acceptable.

Audit testing of two 160 engines was completed the NOX was 4.96 and 4.75. Particulates were 0.05 and 0.061. Another 3 engines are coming up for testing after which we will review lowering the FEL to retain a 49 or 50 state product.

Tooling for the soft seat thermostat to improve the overcooling problem has been ordered. To meet Chrysler launch schedules (August 94), production will begin using identical production tooling owned by another Robertshaw customer. In parallel, Cummins is acquiring its own tooling which will be ready for October 94 production.

Audit testing of two 160 engines was completed the NOX was 4.96 and 4.75. Particulates were 0.05 and 0.061. Another 3 engines are coming up for testing after which we will review lowering the FEL to retain a 49 or 50 state product.

#### Encore

-----

VP44 - based on recent test results, the VP44 appears to be capable of achieving 275 bhp.

Emissions at this power level were measured at .100 gms/bhp-hr BSPT and 3.700 gms/bhp-hr NOX. However, transient response, BSFC and thermal loading on the engine do not yet meet the profile and design targets. Work is underway to address these shortcomings.

Cylinder head - performance of the C1 level cylinder head remains unchanged - significant improvements in emission performance are required to meet our design targets. Plans are in place and intensive development is taking place to improve the performance of the current cylinder head.

#### Marine performance development:

-----

Performance development on the B Series Marine uprate engine (365 hp @ 3000 rpm) has revealed a potential transient response problem that appears to be related to inertia of the dynamometer that is unaccounted for during the transient test.

Work is underway to determine fully understand and quantify the transient response characteristics of this rating.

#### Industrial Performance

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6BTA Uprate -  
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The P-3000 fuel pump that was developed to replicate the performance of the MW fuel pump doesn't. The reasons for this are being analyzed and discussed with Bosch.

6BTA <175hp Elite -  
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The CPL is defined for this product now. A change in delivery valves have improved the low end performance, torque vs smoke trade-off. We need completion of LDA spring definition and cold testing before product is released.

6BT Elite -  
-----

The 110hp at 2400rpm rating for Komatsu is completed and the entire engine has been shipped to Brazil. Working up the rest of the options with design and the release can be completed.

The 165hp at 2500rpm rating is almost completed. Some last minute injector and delivery valve changes have improved hydraulic stability. As with the 6BTA, we need to do some cold testing before we can release the FAP. The A/RSV pump is now displaying a dip in the torque curve before the governor break point similar to what we had experienced with the Nippondenso EP-9 pump. We have alerted Bosch to the "sighting" and we are anxious to hear their response. In the mean time, some discrepancies in data have surfaced between PCO pistons and ones made by KS. We are reviewing the data and are evaluating the test.

4BT Elite -  
-----

The new turbocharger is still giving us good results. We changed the high pressure lines to 1.6mm ID and saw an improvement in smoke performance. Confirmation of pump side pressure has not been measured yet and this could force a change back to 1.8mm lines. In the mean time, a back to back test with of the '91 cam and the '94 cam did not yield the expected result. The '94 cam showed a deterioration in low speed performance. We have circled back to the original '91 cam and now seem unable to duplicate the original test results. Currently we are evaluating the tests and variables and retracing to understand why the test results are not repeating.

Pump Lab  
=====

We have completed 22 of 25 work requests submitted this month.

Equipment:

Bench #1 - running  
Bench #2 - running  
Bench #3 - running

New Hartridge AVM test bench expected in mid August

DESIGN B Series  
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Current Product/Plant Support  
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In response to a request from CMEP concerning a rash of BIS leaks at the oil pressure regulator plug, a detailed investigation into the design of this seal and it mating components was undertaken. The result of this

investigation showed the nominal crush on the o-ring was unacceptably low. In consultation with the o-ring supplier, an alternative o-ring was identified to address this problem. Parts have been made available and are currently undergoing evaluation at CMEP.

#### '94 Emissions

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Design support of efforts to address the B160, 50 State emissions requirements were undertaken via design of a "hybrid" low pressure fuel supply line intended to resolve the "stability" issues resulting from the hydraulic sensitivities of the new revised LPC fuel pump. While this effort has resulted in the design, stress test and release of a new supply line incorporating a length of rubber hose, demonstrated to be effective in alleviating the low speed mis-fire condition experienced, for use at introduction of the new, reduced LPC pumps, design efforts are continuing, in parallel with performance efforts, to explore and package alternative and more effective means of dealing with the emerging overall system hydraulic problems.

#### B SERIES STRESS

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##### ENCORE CYLINDER HEAD/BLOCK PRESSURE FATIGUE TEST

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A test plan has been developed to fatigue test the B and C Encore cylinder heads and blocks. The testing will be done at the CTC Applied Mechanics lab. Fixturing for the tests has been designed and is currently being manufactured. C2 B-Series heads are scheduled to be on test by August 1st followed shortly by C1 C-Series heads. The goal is to determine the integrity of the heads and blocks when subjected to increased cylinder pressures.

##### ENCORE FUEL SYSTEM PRESSURE CAPABILITY

-----

Plans for testing the pressure capability of the Encore fuel delivery system are currently being developed. Areas of concern include the joint between the high pressure line and the injector, the injector body, and the high pressure line. Evaluation of current pressure fatigue testing methods (none of which area currently available at METC) has shown that it is somewhat difficult to generate the required pressures efficiently. All of the pressure fatigue rigs that have been evaluated use a diesel fuel injection pump as the driver, which results in a slow test rate, marginal pressure capability, and insufficient pump life. Options being considered include the use of a servo hydraulic testing system (MTS), or building a dedicated rig at METC with a yet to be determined injection pump.

##### ENCORE VALVE TRAIN

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B-Series C1 Verification: Concerns were raised in the Valve Train components team about the high cylinder pressures previously measured a C1 engine. The pushtube loads measured were also considerably higher than those predicted by Valsim. Calibration of the Valsim model using the high pushtube loads resulted in increased Hertz stress on the cam, and concerns that the pushtube loads were approaching the buckling limit.

Exhaust Valve Test vs Backpressure: Significant time and effort has been put forth in the development of testing on the Encore C1 valve train with an exhaust brake. Concerns centered around the use of hydraulic tappets and exhaust brakes have driven the need to determine the amount of exhaust valve float as a function of speed and back pressure. Testing is scheduled to begin in July at ETS.

#### TLEV

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Full load vibration spectrums were taken on the EGR valve. The supplier has agreed to develop a vibration test that simulates the measured spectrum.

CASE SUPPORT:

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The rear face of the stiffened block design has been photostressed, and work begun on determining the most critical strain locations in support of the Case MX30 Ag tractor project. At the conclusion of the photostress work, a cylinder block will be strain gaged and provide to Case for testing in application. Support has also been provided on the X95 Loader/Backhoe project. The Case Burlington facility was visited to review the installation and discuss possible solution to flywheel housing failure issues. Strain gage locations were supplied to Case and interpretations/recommendations given concerning the results of the testing. A cast iron flywheel housing has been recommended.

C SERIES

=====

1994 Product

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Two recent C300 emissions audits performed at SWRI resulted in failures (.106 PM). The LDA pump setting was out of specification by a wide margin. Quality has been notified to implement a corrective action. Resetting the LDA to the correct specifications reduced particulates by .010 g/bhp-hr and resulted in emissions below the FEL.

Edison

-----

Four CV engines were built during June. Issues highlighted (non-available parts, etc) are being addressed for the remainder of the CV builds scheduled for late July.

CV Calibration work constitutes a major part of the C Performance workload. Much of this activity will be transferable to the Celect software. Controls/stability mapping and tuning work is underway. Performance limit-diagram mapping has also begun to establish safe boundaries for best BSFC calibration.

CV installation in the METC Ford vehicle is nearly installed in preparation for vehicle driveability/stability testing as well as EMI testing planned for late July.

Elite

-----

A decision was made to use the P3000/RQV-K governed pump for higher Hp (250 & 260Hp) CTA product. The negative torque control offered by the RQV-K will allow a reduct in boost pressure reducing the heat rejection to coolant impact. The 260Hp P3000/RSV will need to be retained for Combine applications due to their tighter governor regulation requirements.

A reduction in LPC to 2.8mm has resulted in better BSFC at the same NOx level. Robustness against restriction and altitude effects will be performed with this new LPC direction. July efforts will focus on low speed torque improvements still required for some markets. Evaluations include increased piston height and exhaust manifold/turbo flow improvements.

Design work is ongoing on several new items which have been added to this program. New exhaust manifold cores have been designed for prototype HMFO manifolds and the HMRO manifolds will follow. The P3000 high mount PTO gearhousing is being converted to a permanent mold pattern and research is beginning on a non-PTO version requested by JI CASE. The grid heater work has



been diverted to explore the capability to mount the grids inside the air box. The flow model has been constructed and is ready for testing. If this is not acceptable, work must resume on the current prototype to see if it is possible to make the injectors serviceable with that design. Design and testing schedules have been set up to determine which if any components are in need of special care to achieve production in 1996. The long leadtime items now are the manifolds and the oil pans and they are being given priority.

#### Current Product Support:

The breather design has been design reviewed and requires some modification. This work is underway and should be completed before the end of July. The next step will be to get prototypes underway. The changes are being made to optimize the design and make it more compact.

The engine mount study is proceeding slowly due to problems with the models being analyzed. Some changes to the loading were made which caused problems with the solutions. Rasna has been contacted and they are working on this issue.

#### EuroNoise

Field testing is successfully progressing with the installation of 3 U.S. field tests complete. Noise kits to support the first batch of U.K. field tests have been sent to Darlington.

Work continues with Blatchford who supplies the noise enclosure around optimizing the design. Issues around the quality of the previous enclosures are currently being worked and progress is being made. Joint meetings between Blatchford and Cummins are being held weekly to finalize the design of the enclosure.

Work has begun jointly with Holset around developing a pump-gear mounted damperto reduce torsional activity created by the various inline fuel pumps beingused on the C Series. Recent test activities on both the C and B Series have shown favorable noise reduction by adding damping devices to the fuel pump gear. Technology is currently being developed to quiet the B Series front end and is being reviewed for potential benefit on the C Series.

#### Marine Update

Although the 365hp B is the primary path for the Uprate program with the earliest introduction date, work completed on the 465hp C to date is very encouraging. While FAP testing is not complete, steady state testing parameters have come close to meeting the product profile around smoke, cyl pressure, turbine inlet temp, etc. While performance testing such as transient, cold start, and possible injector optimization have not been completed, early results look good.

Design Resources required of METC to support the pump resource part of the project have been identified and PCR's have been generated to track this work. Working with CMC, many of new design requirements have been minimized by making use of currently available options or options being designed and developed for other programs such as Industrial Emissions.

With the ever increasing amount of electronic engines at METC, many of the test cells are being upgraded to be fully compatible with the new hardware/software. In addition to test cell upgrades, training classes have been scheduled and will

continue to familiarize those working with the electronic system both on engine, the pump and with the Engineering Service Data Network (ESDN).

#### Encore

June manpower continued to improve but was still below forecast. Support was .9 and 1.5 short of forecast for exempt and hourly, respectively. July should see growth in both areas.

Current plans for the increased displacement C Encore product are to maintain the 114mm bore with an 8.85 L displacement. Plans have been established for a backwards compatible engine block which can be used for both displacements. Testing of the concept design will begin during the next two months.

Activity continues to focus on issues related to the C1 C builds. Major issues stem from delays in the block, head, and camshaft delivery. Casting issues with the C block were unable to be resolved through machining adjustments. These issues have resulted in a delay of the C1 build/start-up originally planned for August 1. Recovery plans are under investigation. The C1 start-up will most likely be delayed until September.

One significant issue recognized to-date is the strain on the local supply base due to the large number of engine programs using the same suppliers. Block progress was affected by Apex and the cylinder head affected by the B Encore program. Future discussions/considerations need to focus on local supplier capacity.

#### CYLINDER HEAD / VALVE SEAT INSERT ANALYSIS

A finite element model of the current two valve C Series cylinder head, valve seat inserts, and valves has been completed and the first of several load cases has been analyzed. The first analysis consisted of simulating the process of installing the inserts into the head. The results of this analysis showed high tensile stress in the valve bridge and compressive stress in both of the inserts. Experimental measurements were then made to verify these results and confirm the accuracy of the technique used to model the head/insert interface. Strain gages were placed on the valve bridge and on the inner surfaces of both inserts. The strain levels measured during the installation process showed excellent correlation between experimental and analytic techniques.

The second load case consisted of applying thermal loads to the model in addition to the assembly load. The results of this analysis are still in the process of being correlated to experimental temperature data. This analysis will show the effect of thermal loads on the press fit as well as the cumulative stress state in the bridge and inserts.

After studying the effects of geometry and insert material changes, this modeling technique will be used to optimize the C Encore head/insert design, and B Encore insert design if required. The technique has been calibrated and proven accurate, providing a high degree of confidence in the upcoming Encore analysis.

#### CYLINDER HEAD/BLOCK PRESSURE FATIGUE TEST

A test plan has been developed to fatigue test the B and C Encore cylinder heads and blocks. The testing will be done at the CTC Applied Mechanics lab. Fixturing for the tests has been designed and is currently being manufactured. C2 B-Series heads are scheduled to be on test by August 1st followed shortly by C1 C-Series heads. The goal is to locate the weak areas and determine the

overall integrity of the heads and blocks when subjected to increased cylinder pressures.

Ricardo North America has submitted a quotation for identifying the design changes needed to increase the bending and torsional capability of both the B and C Encore block/powertrain systems. Contract details are being worked with the anticipation of approval in mid-July.

#### FUEL SYSTEM PRESSURE CAPABILITY

-----

Plans for testing the pressure capability of the Encore fuel delivery system are currently being developed. Areas of concern include the high pressure line/injector joint, the injector body, and the high pressure line. Evaluation of current pressure fatigue testing methods (none of which are currently available at METC) has shown that it is somewhat difficult to generate the required pressures efficiently. All of the pressure fatigue rigs that have been evaluated use a diesel fuel injection pump to generate input, which results in a slow test rate, marginal pressure capability, and insufficient pump life. Options being considered include a servo hydraulic testing system with mechanical amplifier or a traditional injection pump with increased capability.

#### VALVETRAIN/OVERHEAD

-----

Experimental measurements on the B Encore valvetrain continue to show significantly higher valvetrain forces than predicted by VALSIM. The increased loads have generated additional concerns about cam lobe contact stress and pushtube buckling margin. Efforts to understand the discrepancies in the analytical and experiential results are on-going, with several issues being studied. The outcome of this analysis will also apply directly to the C Encore valvetrain.

#### CONNECTING ROD

-----

The initial stage of the rod analysis consisting of the following exercises is complete.

- Literature Search : Four technical papers were identified and studied in depth.
- FEA Research : Discussion with CTC FEA expert and review of previous rod models
- Manufacturing Input : Discussions on machining issues and timing
- Metrology Input : Discussions on dimensioning, feature variations,

Based on the information gathered, critical areas for investigation have been identified. A strategy for the rod design, analysis, and testing has been developed. The analytical technique will be based on FEA with calibration to existing current product experimental data. A photoelastic model is being considered to understand the stress state in the blind hole region.

#### CRANKSHAFT

-----

The torsional stiffness of the increased stroke crankshaft has been calculated for use in the mass elastic torsional model. Torsional predictions will begin as soon as the oil film and bending stress study (CTC) yields the mass properties.

PCR

The total number of open PCR's for June for B and C remains 570. We had 30 now the administrator of the PCR work scheduling and we had our first total new PCR's for June. Eleven were cancelled and 30 were closed at the review meeting. Sally Burke has left Cummins and is no longer heading the PCC. That position has not been filled. It is expected that the position should be filled within the next month.

CONTINUOUS IMPROVEMENT ACTIVITY - DOCUMENT QUALITY IMPROVEMENT TEAM

The DQIT has informed all worldwide engineering groups of the drawing criteria and has given the task of assessing the quality of drawings we are receiving to the drafters. Feedback will be given to the originators on drawings needing more/better information until October 1. After that time, ER's will be rejected and returned to the originator for additional work.

The DQIT has expanded its customer base to include the specs analysts. A meeting was held with them to discuss their concerns and to explain our plan for returning ERs to the originators if more info is needed.

The releases reviewed by the Team for the month of May shows 80% meeting the guidelines compared to 70% the previous month.

ADMIN/DRAFTING ACTIVITY

|                                         | MAY     | JUNE    |
|-----------------------------------------|---------|---------|
| Total ER's received:                    | 208     | 194     |
| ..Critical ER's received:               | 22      | 24      |
| ..Plant ER's received:                  | 24      | 12      |
| Total ER's completed:                   | 171     | 212     |
| ..Critical ER's completed:              | 21      | 27      |
| ..Plant ER's completed:                 | 24      | 15      |
| Total Throughput Time for ER's:         | 53 Days | 49 Days |
| ..Total Throughput Time for Criticals:  | 57 Days | 40 Days |
| ..Total Throughput Time for Plant ER's: | 25 Days | 45 Days |
| Total Month-end Backlog:                | 383     | 365     |
| ..Month-end Backlog for Criticals:      | 34      | 31      |
| ..Month-end Backlog for Plant ER's:     | 18      | 15      |

COST REDUCTION

C INJECTORS AND DRAIN LINE

Design modifications have been completed on issues raised during the follow-up design review. These include assembly ease and o-ring integrity. Design iterations have been checked with potential suppliers for manufacturability. The injectors and leak-off system have been submitted to MCP for quotation and prototype inquiry.

B WATER INLETS

Quotations for Ford B water inlets using lost foam casting show a cost reduction potential of approximately \$150,000/yr. This is due to the elimination of several machining operations. Process capability must be further analyzed to determine technical feasibility. Quotations for two other B water inlets using an injection molded thermoplastic show a cost reduction potential of up to \$250,000/yr. Necessary changes in alternator bracketry will determine if this is viable in terms of total cost.

#### NWD TURBO OIL DRAIN TUBE

Preparations have been made to allow for testing of the solid tube and NWD no-leak fitting. A 'D' release and testing have been delayed until questions regarding return on investment are resolved.

#### CAST ALUMINUM INTAKE ELBOW

The part has been modelled on ProE to facilitate production tooling. Sample parts should be available in 6-7 wks for final quality checks. (\$120,000 annual savings)

#### M12 B SERIES MAIN BEARING CAPSCREW

Sample capscrow inspection (dimensional and metalurgical) is complete. No issues found with regard to metalurgical properties, a few discrepancies surfaced during the dimensional inspection (pitch and major diameter, head height, and underhead radii) that will be resolved in parallel with preliminary structural testing. Samples blocks have been delayed due to a design (drill specification) error, tools required to salvage the five prototype blocks have arrived and been forwarded to CDC. Blocks will be available the second week of July, 4 weeks behind schedule. (\$672,000 annual savings)

#### B/C THRUST WASHER

Concept design review on ML-KS thrust washer proposal held June 3 with B and C representatives concluded that new design, at the current quoted cost, is not viable for current B/C product. Cummins asked ML-KS to quote narrowed cross section 360 degree washer design targeted for C Encore consideration.

#### C VISCOUS DAMPER

Integrated pulley/viscous damper project has been reviewed by Holset and will be made part of their 1995 AOP. The new damper is expected to be a significant cost reduction over the current product (\$60 plus on an option basis) but will still not be competitive cost-wise with the tuned rubber dampers. A product profile will be the first task the Holset/Cummins project team will tackle in Q3.

#### CHRYSLER FLYWHEEL

Casting and machining cost reduction quotes for the proposed design have been received, totals are \$2.82 (ductile iron) and \$4.78 (grey iron) design. Finite element analysis work to reduce predicted stresses to a level below design standard limits for grey iron are underway.

#### PLASTIC FUEL LINE CLAMPS

Proof of concept testing of prototype plastic fuel line clamps with rubber isolation has been delayed, testing is now scheduled for the week of July 11th at CDC. At 55% of the current cost, the plastic version of the 3 line clamp has the potential to be a \$150k/year cost reduction. Other clamp configurations will be considered after successful proof of concept testing is complete on the high volume 3 line clamp.

#### PLASTIC OIL PAN

The model has been completed and is to be reviewed the week of July 11. Prototype part delivery may be impacted by a delay at Creative Tool. Parts

will be available 3 weeks after receipt of machined components.

#### WABCO VACUUM PUMP

The noise issue has been resolved, and prototype parts were rec'd at METC the week of 6/20. Testing has started and no issues have been identified. Wabco is addressing the loss of schedule time due to the delays by Getrag. A schedule and final quote are expected the week of July 11.

#### PLASTIC REAR SEAL/RETAINER

We have reached an "agreement in principle" with CR Industries concerning warranty participation on the new rear seal and retainer. A meeting has been scheduled (July 25) with CR and MCP to finalize the proposal and start the prototyping process.

#### RELIABILITY

##### Encore

Top ten lists (of RPH, BIS, Leaks, Mission disabling and Durability failure modes) for current product were generated and will be assigned to the respective component teams. The component teams will be required to develop reliability plans to show how they've addressed each item. The plan should contain steps of how the team plans to prove that the item is no worse than current levels and will be reduced by 50% by the year 2000 (per the Encore contract).

S. C. Milloy (SEAN)

#### DIST-\*JPJ-NEWS

|              |               |
|--------------|---------------|
| Barrett, P M | Beyer, S      |
| Brower, D R  | Brown, C D    |
| Bush, J W    | Clarke, C L   |
| Colvill, J K | Connor, D M   |
| Corbin, S A  | Davidson, S D |
| Dees, B      | Doup, D E     |
| ESTEP, T L   | George, F C   |
| Ghuman, A S  | Graham, K T   |
| HARRIS, M    | Kamel, M M    |
| Kieffer, T P | Klaus, J G    |
| Lang, R E    | Ley, C J      |
| Lin, C S     | Milloy, S C   |
| Molewyk, T L | Moore, L O    |
| Moore, R L   | Morgan, L T   |
| Murvin, E T  | Neil, S W     |

More..

6

DATE: August 18, 1994  
TO : DIST-C  
DIST-CCPE  
DIST-6880126  
FROM: S.C. Milloy (SEAN)  
SUBJECT: C Series July Newsnotes

## C Series

### Edison

-----  
Dyno testing of the Edison engine has centered around SOI stability with the VR and Hall Effect sensors. Currently, the VR sensor is very air-gap sensitive in terms of signal strength and signal/noise ratio. The EPS sensor is mounted in the location that the engine lock pin is currently in, and the lock pin hole in the engine cam gear is being used to trigger the TDC signal. The engine and systems teams are now looking at parallel paths to release the VR and Hall effect EPS sensor.

A Ford L8000 tractor upfitted with the Edison engine was driven to Downers Grove, IL for initial vehicle EMI testing. The test was a success for the most part, with some instability noticeable with RF of 60mHz. This is not felt to be significant in terms of program impact, but more as a watch out for further development in the CEL anechoic chamber.

Work has progressed on the harness design for the Edison program. The harnesses will be structured as ID 13's to allow for service of components.

The block release has been written to incorporate the new MRE block across the board. In process, we have discovered that the boss to be used by the water temperature sensor will need to have some material added to minimize the amount of interrupted cut on the spotface. The release is being held until this issue is resolved. Using a longer sensor which is unqualified is considered as too risky at this point in the program. All fuel lines for MRE have been redesigned for UBRID material. Only samples were produced from HS10 and these part numbers have been removed from structure.

The hall effect sensor has been chosen as the prime path for Edison. Design work is now concentrating on the housing for the sensor.

The first Edison engine was installed into an endurance TC at Building 14 to sort out any engine / TC compatibilities. Issues with the engine speed sensor as well as noise from the TC have delayed testing. Troubleshooting is still in progress.

### Elite

-----  
Elite 6CT performance development - 215@2200 emissions development is continuing with major area of focus on improvement of NOx/BSFC/HRJ tradeoff. Current status of development is 0.388 rated BSFC at 6.3 Gr/BHP cycle NOx.

This BSFC is 7.8% worse than the non-emissionized product. The FAP is nearing completion, pending Heat Rejection improvements.

6CTA performance development - 260Hp P3000/RSV Fap is near completion pending final performance/smoke/emissions results. The last leg of development is centered around evaluation of reduced LPC in order to improve the NOx/BSFC tradeoff.

The Elite gearhousing tooling has been determined. It will be a sand-cast part and the drawings will reflect this direction. The prototype tooling will be used for initial production as it is good for about 2000 pieces. An L release will be written next week to complete all drawing details and structure work for CSL.

The Fead work for the special drives has been completed and a D release is being prepared. This work will also be applied to the automotive configurations. A change of supplier has led to the need for some additional drawing modifications. Holset, the original supplier, is capacity limited so A J Rose will now be the supplier for the spun alternator and fan pulleys.

Oil pan and suction tube prototypes have been procured for the enlarged oil pan testing. Applications has received data to present to customers to decide whether such a pan would be feasible in installations. Marketing feels today that about half the customers could use the larger pan.

An FE model of the 30 quart pan was initiated on the first of August. A fabricated pan has been made to collect pan flange strain data for model calibration. The flange strain data will be measured on the second week of August and the structural concept evaluation should be finished by the end of August.

The reduced core HMFO manifolds have been ordered and are now in process of being prototyped at TUPY. These manifolds are required for the consistency testing for the CT. Testing will be done to determine if they will be used on the CTA product as well. If they can not be used, new TB options will be required for the CT product.

#### Transit Bus

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A 94C Transit Bus drivability improvement through the use of the new small volume exhaust manifold and 17cm<sup>2</sup> turbine casing has yielded approximately 12% increase in response at the same particulate level as the current product. Final settings and testing in a transit bus are being planned.

#### EuroNoise

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EuroNoise engineering activity is working toward establishing stable designs for four major noise options. These include:

- Oil Pan isolation and enclosure design
- Engine bedplate
- Fuel pump drive damper (w/Holset support)
- Close fit piston design

All field test engines for both US and UK test sites have been built. The



three US engine have been installed with no issues identified. The six UK engines are scheduled to be in operation during August.

FMEA's have been completed recently on the majority of noise components for the C engine.

Current Product Support:  
Product Problem Correction

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Front End Upgrade:

The transmission 'shift shock' test is being conducted on the production level front end components as a final validation test. This 500hr test is nearly complete.

The pilot build of Case 7220 tractor engines (SO 50860) is underway at CDC using hardware from production tooling. The first 9 units will be pulled off line to measure front crank seal TIR in the fully installed condition. The front covers for these engines were pre-measured for front seal TIR at the supplier (Arvin). The front seals are being installed by Arvin. The TIR of the front seal remaining 89 units will be randomly checked. The build schedule is 3 units each on 7/28, 8/1 & 8/4 and then 89 on 8/8. On 8/8, all 89 units will be batched together and will run across full production equipment, (i.e. multi-spindle torquing machine).

PPAP's are in process on the front cover and the gaskets. A release was submitted for the front covers to close out any issues regarding PPAP's and print discrepancies. Included in this release (940195-593) is also a modification to the covers to provide increased clearance around the engine mounts.

HS-10 fuel lines

Reliability engine testing has raised a serious concern with fuel line breakage on automotive products produced since April '94. In April, a new fuel line material was introduced. Discussions with the supplier have indicated that heat treatment processes were significantly modified after the source approval testing was completed and just prior to production launch. Early indications are that a significant field exposure exists with engines built with these lines (approximately 6000 units on C). Production returned to the former (UBRID) material on July 18, 1994.

High pressure fatigue testing of Usui HS-10 fuel lines is in progress. Lines are being tested to 30,000 psi load pressure to quickly determine the fuel line fatigue strength.

Front end noise

The viscous damper is being released against industrial and automotive configurations in order to address front end noise and A pump shaft breakage. The viscous damper is larger in diameter and does result in interference with some front support designs and inadequate clearance with others.

Finite element analysis of modified 'pad style' front mounts to accomodate the viscous damper has been completed. The analysis shows the stress levels to be acceptable with the modifications. The release for the changes has been written and submitted to drafting. Analysis of the 'barrel' type front supports in underway. Initial indications are that modifications

will be more difficult to achieve without more extensive changes to alleviate structural concerns.

#### Exhaust manifold capscrews

Exhaust manifold capscrews degradation (rust, corrosion, etc) is a significant issue in most applications resulting in breakage upon removal and possible damage to the cylinder head. Oven thermal cycle testing of exhaust manifold capscrews has been completed. The test compared high temperature tempered and stainless steel c/s's against the current c/s. The breakaway torque data shows the stainless steel capscrew to be the best choice. Further testing is in progress.

#### Oil consumption improvement

Oil consumption reduction is necessary in order to improve emissions compliance robustness, remove the catalyst from the Edison product, meet very stringent '96 Transit particulate emissions (.05 g/bhp-hr PM), and reach goal of not requiring the addition of oil (no top-up) within the oil change interval.

Oil consumption development work has continued. The second iteration of the increased 2nd land cut back has repeated the 50% oil consumption reduction at mode 5 condition. Rated oil consumption improvement was less significant. Testing with no end gap chamfer top rings resulted in significantly scratched liners and testing was scrapped. Testing was completed with varied ring gaps and showed little effect on oil consumption.

The baseline engine for a liner honing evaluation has begun testing. This engine has the increased cut back feature with std ring pack.

Metal Leve has completed some simulation on the J groove feature at rated condition. They propose a 3.0 mm cut on the piston 2nd land (we are at 2.5 currently during testing) plus they see an added benefit of a pin offset. We have asked that they do a simulation at part throttle.

#### Oil carryover

Breather work continues as a new, more compact design is being investigated.

#### CDCPE Test Cell Facilities

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Five DOE engines have been completed to date. The last two engines (of the 16) were line set on 8/2/94.

The RFA to bring compressed natural gas (CNG) into Test Cells 2 and 3 was approved. Installation will begin as soon as parts are obtained.

The method to be used for finding CNG non-methane hydrocarbons will initially be the bag collection system with analysis with a Gas Chromatograph (GC). The Quality Lab at CDC will do the analysis. The GC is in-house and some of the technicians have been to CDC for training. We hope to duplicate the measurement scheme used by CTC.

Major changes were made to the combustion/dilution air handling systems for the test cells. The humidity steam injection system was extensively modified. Controls still need to be refined. With the high humidity we have been experiencing we have been able to get stable dew points by cooling the inlet air and not using the steam injection.

#### ISO

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As of 7/25, Product Engineering current percent was 74% previous percent was 53% for ISO action summary. There are 25 items to be completed with only 41 work days before the audit. Key elements that need to be completed are NETS, DSO, PM, Calibration and Database Backup procedure. TQS procedures, Deviation and RES, were submitted in June and will be incorporated in the Plant Quality Manual. Aperture card file procedure was approved and became effective on 7/25.

Encore

July manpower support for the C program was about equal to that in June. Exempt support was 7.3 man-months and Hourly was 2.6. Growth is slow in the hourly area primarily due to lack of hardware. Vacations had a major impact on the exempt support.

During machining of the C1C head at PECO a problem was found with core float in the rear water jacket and cope which caused a machine breakout into the water jacket area. Several castings have now been inspected and found to not display the same casting problem. We do not feel that this will limit our ability to build engines in October.

The Block tooling modifications are continuing at Cunningham per the revised delivery schedule. Priority conflicts with the Apex group continue to impact our ability to get our work done in an efficient manner. The block is the pacing item for our October 4th. start date. Progress is monitored daily.

Reliability issues have been shared with all of the active component system teams to develop improvement plans for current issues as well as test plan for new components. The final four component teams will be started within the next 45 days.

Split Angle Connecting Rod

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Transfer of the ProEngineer model to Rasna has been complicated by the use of mismatched units in ProEngineer versus those required by Rasna. Since dynamic analysis is the primary motive for the use of Rasna, an alternative method for model generation was desired.

The IGES transfer from ProEngineer to Ansys resulted in unacceptable mesh control due to complex fillet and blend radii. Therefore, a finite element model of the split angle rod is being constructed in Ansys 5.0A. This model can be transferred successfully from Ansys to RASNA for evaluation of inertia and gas loading as a function of crank position. These boundary conditions will be loaded back into Ansys for the structural evaluation.

#### Cylinder Head / Seat Insert Analysis

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The thermal stress analysis of the current 2 valve C Series head has been completed. Material tests to determine the compressive yield strength of the valve seat inserts at elevated temperatures are currently in process. These results will then be compared with the stresses calculated in the FE model. This model will also be used to study the effect of insert geometry and material changes on stress levels. The FE model of the Encore cylinder head has been completed. The first load case, insert assembly loads, has been completed. The thermal stress analysis will be completed by mid August.

#### Cylinder Head Pressure Fatigue Test

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Fixtures for the B Series cylinder head pressure fatigue test have been completed. A current production 2 valve head will be run to troubleshoot the test setup and to develop a baseline for comparison with the Encore head. This work is scheduled for the first two weeks of August. Testing of the Encore B head will begin immediately upon receipt of C2 level parts. Fixtures for the C-Series head are still on schedule.

#### Valve Train Model

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A valve train rig has been designed to simulate the current B Series valve train. The rig is a single cylinder table-top model which allows investigation of parametric effects on valve train response and measurement of previously inaccessible variables. The hardware is expected in early July. As soon as the model is correlated to actual engine data, an analogous rig will be designed/manufactured for Encore B/C development.

#### Headgasket Development

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A method for measuring the combustion seal load during engine assembly and operation has been designed. The test system hardware is being machined and is expected the second week of August. The system will evaluate the dynamic loads on the combustion seal in addition to the thermal shift. Testing on prototype Coopers Payen and Felpro gaskets are scheduled to evaluate cylinder pressure capability versus liner protrusion accounting for thermal effects and plastic deformation. The prototype gaskets for this evaluation have been received.

#### High Pressure Fatigue System

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A high pressure fatigue system has been designed and 30,000 psi (2112 bar) capability has been demonstrated. This system provides adequate capability to pressure fatigue injector bodies, fuel lines, and other fuel system components exposed to injection pressures. While this system was designed primarily to evaluate Encore components, it is currently obtaining pressure fatigue data on USUI HS-10 fuel lines.

#### Crankshaft Torsional Parameters

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The inertia and stiffness values of the D crankshaft have been calculated using the BICERA method. This data will be used to completely evaluate the torsional activity in the D engine and the capability of the flywheel/crank joint. This evaluation is scheduled to begin in August.

S. C. Milloy (SEAN)

CC : DIST-CNEWS

DIST-\*C

|                |                  |
|----------------|------------------|
| Buchanan, J C  | Bush, E E        |
| FRANZWA, R A   | Hager, F M       |
| Johansen, G A  | LIN, C S         |
| Marthaler, M J | Milloy, S C      |
| Neil, S W      | Ritzline, L A    |
| Virnig, D M    | Wolff, K         |
| Klaus, J G     | Sowerby, P       |
| CORT, A        | ROGERS, D G      |
| Weikert, J M   | Yager, J H       |
| BUSCH, D A     | SEVAKIS, A M     |
| GASTON, N      | BEYER, M A       |
| Hovin, L E     | DOWNING, D H     |
| KOVRT, A G     | Prentiss, L A    |
| RICH, J V      | Purcell, J J     |
| WASWICK, C E   | Scarborough, J M |

More..

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| Yager, J H   | Bose, T N      |
| Queiroz, J T | PASQUOTTO, L A |
| Bolina, A O  | Sowerby, P     |
| Andrie, M J  | Molewyk, T L   |
| Johnson, P E |                |

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| Allen, W C       | Alston, G       |
| BUEL, T J        | Coggins, H F    |
| Cole, J A        | Collie, T R     |
| Deeds, J T       | Denton-Jr, J W  |
| Dickens, D T     | Dover, R G      |
| Faison, K        | FISHER, K J     |
| FRANZWA, R A     | JOHNSON, J H    |
| Kloosterman, G C | KRASZESKI, D J  |
| LANG, M          | LEBEGUE, J S    |
| Long, D G        | MARINO, T R     |
| MELROSE, M W     | Menard, J D     |
| Murvin, E T      | NELSON, R E     |
| OCCENA, S W      | PANETTIERI, R A |
| Richardson, L A  | ROSSI, R A      |

ST-GEORGE, O  
More..

Stith-Farmer, M

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Bolina, A O  
Bean, S W  
Yager, J H  
GALE, T J  
MANDT, B  
WISSMANN, D S  
Strawman, R A  
Andrie, M J  
FAISON, S A  
Connor, D M  
WATTS, R D

PASQUOTTO, L A  
Molewyk, T L  
Bose, T N  
Herlitz, D L  
SOULTZ, B L  
Barrett, P M  
Schisler, H E  
CORBIN, K D  
Turner, C M  
Sowerby, P  
Kahlenbeck, J D

DATE: September 23, 1994  
TO : Ms. S.J. Davidson  
FROM: S.C. Milloy (SEAN)  
SUBJECT: C Series August Newsnotes

## C SERIES

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### CURRENT PRODUCT

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Emissions testing of ISIR samples of the new 5-hole injection nozzle for 94C 210/225 HP engines was successfully completed. The results follow those seen with the development samples. The Nox and particulate have been reduced by 0.15 and 0.01 Gr/BHP-hr, respectively. There was also no change in torque curve or LDA fueling, meaning no injection pump modifications will be necessary to accommodate these new injectors. A design review was held, with the consensus to approve for production. Final issue remaining is regarding whether a new CPL release will be necessary. Full production should begin within 1 month.

The baseline engine for the liner honing evaluation was tested. Oil consumption was where expected, 45 gm/hr rated load & speed - 12 gm/hr mode 5. This engine has the increased 2nd land cut back design feature. Results from a second oil consumption test with the 2nd land cut back feature repeated these results adding confidence in the cut back design.

## ELITE

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A design review of the Elite 6CT and 6CTA #1 curve ratings was held to present the current status of development and discuss issues wrt heat rejection and turbine inlet temperatures. The 6CT-215 is complete, with final testing of particulate emissions prior to removal of the FAP from the engine. Turbine inlet temps are just below 1200 deg F at rated, with rated BSFC of 0.384, a 6.7% change from the non-emissionized current product. Rated heat rejection to coolant is 8.6% up from current product.

The 6CTA-260 is near completion, pending a check of secondary injection margin with 120mm<sup>3</sup> retraction delivery valves.

The D1 reliability testing is underway. One 6CT Hot Box engine test was completed. Three additional 6CT engines were built at CDC with testing to begin during September.

New manifolds with reduced cross sectional area represent the longest leadtime item for the Elite program. Design activities are focused on finalizing the production designs as quickly as possible to begin production tooling.

The M3/M4 is scheduled for Oct 19 with the technical review set for Oct 3.

## EDISON

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Limit diagram testing is continuing in test cell 7 with full performance documentation completed on 4 injection timings. Pending review of the limits as they pertain to the current emissions timing lookup table, the CV

calibration will be complete in terms of fueling and timing.

Efforts to support build and production test of 40 D level builds during Q4/94 are on-going. Timely completion of design details (revised lower fuel pump support, low pressure lines) as well as controls support to assist production test is required. It is essential that CDC production test to properly prototype the system.

An M2 is scheduled for Oct 13 with the technical review date set for Oct 6.

Encore

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August manpower support for the C program was up 2 from July. Exempt support was 8.2 man-months and Hourly was 3.4. Next month should bring a large hourly increase as we begin building engines. We were 2.5 people short of the forecast for August. September forecast changes from 14.2 to 18.9 people.

The machining of the C1C heads at PECO is continuing on samples which passed pressure test. At this point in time we are one week away from our first two finished machined heads.

The block tooling modifications were completed at Cunninghams within 3 days of the plan. Five good block castings and 2 scrap setup castings are at CDC being machined. As of 9/1 two blocks had made it through the initial machining and appeared to have a good chance of giving us testable parts.

All of the component teams have been identified and started except the applications options team. The applications team will be kicked off within the next two weeks.

C1C test plans have been finalized and scheduled into the appropriate performance and mechanical test cells. The first build is expected to be complete in time to meet an Oct 5 C Encore engine start-up date.

The FMEA for the cylinder head is 95% complete. We are half way through assigning probability numbers and design verification actions. The team will then use this data, along with recent engine test and warranty data to establish testing requirements.

Test to failure has begun on current engines to establish a baseline for testing on Encore. The first test involved running the engine at 2600 psi peak cylinder pressure at rated speed for 10,000,000 cycles followed by increasing the cylinder pressure to 2800 psi for another 10,000,000 cycles. The engine successfully completed the testing at 2600 psi, but failed the cylinder head at a head capscrew boss after approximately 60 hours at 2850 psi. The engine will be rebuilt and will repeat the test to see if the same failure occurs.

Product Problem Correction

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Front End Upgrade :

Introduction of the improved front end components to resolve oil leakage is planned for late September. A pilot build to support reliability and EQA



testing as well as a 89 piece customer run-off were completed during August with no leakage or problems found.

The service gasket is in process at the supplier. The design was finalized and the prototype tooling is being procured. Timing for the gasket is late October. A new front cover gasket for service is also being procured from the supplier. This uses a new material, which has been successful on other joints. Timing for the these gaskets is late September.

#### CDC Product Engineering

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Eight DOE engines have now been completed. The pre breakin steady state tests have been completed on the remaining eight engines. The last four engines to be broken in are at ETS awaiting test cell time.

Heat rejection instrumentation is now being used in the test cells. Forced cool down of emissions engines is now being used to reduce the cold soak time between runs. This capability has helped in to reduce the time it takes for the DOE and Audit emissions tests.

Kimberly Pugh was hired into Design group, effective August 16, 1994. Kimberly was previously an Engineer on the CDC Rod Line.

Continued our focus on ISO9001 implementation projects. Internal audits are scheduled throughout the month of September to be sure that we will be ready for the BVQI auditors on October 4-7.

Modified the C-Series suction tube to eliminate interference with the new connecting rod bolt.

Worked on Komatsu failures of B-Series fan hubs / front of block.

- Strain gaged blocks.
- Measured dynamic moment on FFOB with two fan hubs and three fans.

Completed planned fatigue testing of microalloy rods.

Worked on cracking Navistar heads, in area of relief for fuel pump drain banjo screw.

G. A. Johansen (GARY)

CC : DIST-CPERF

DIST-\*CPERF

|              |               |
|--------------|---------------|
| CORT, A      | DOWNING, D H  |
| GLENN, DOUG  | Johansen, G A |
| OVALLE, G    | SAH, F J      |
| SEVAKIS, A M | SUN, H        |

S. C. Milloy (SEAN)

DATE: October 26, 1994  
TO : M. PERRIN  
FROM: S.C. Milloy (SEAN)  
SUBJECT: C Series September Newsnotes

#### Current Product Activity

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Upgrades to the C Series front end to eliminate oil leakage in the field were implemented in production in September. Changes include block casting changes, gear housing casting changes, edge molded rubber steel gear housing gasket, new gear cover for liquid gasket, formed-in-place gasket (gear cover to housing), new capscrews, and increased capscrew torque. Development of a service gasket to provide an improved field fix for current engine blocks/housings is underway with targeted introduction by end of the year.

PPAP approval of 5-hole injectors for the low Hp C Series 94 automotive product was completed during September. The 5 hole nozzle reduces NOx emissions by 0.3 g/Bhp-hr. This reduction will allow a test speed specification reduction of 200rpm to maintain equal NOx emissions in an effort to reduce particulates. The 200rpm reduction reduces PM emissions by approximately 0.015 g/Bhp-hr which should eliminate the need for PM credit usage.

Activity has been underway to create a rating suitable for cement mixers. The C is an ideal cost effective alternative to the M11 and competition. Field evaluation indicated that the C300 required improved low end performance to meet customer response requirements. Increases in the no-air and AFC were evaluated and the customer response has been very positive. Work is underway at METC, Bosch, and CDC to deliver this rating by Jan 1, 1995. Opportunities to pull this release date forward are being evaluated.

Cracks were discovered in the pilot bore for flywheel 3906393. A dozen flywheel castings were strain gaged and analyzed for residual stresses. High residuals were found in parts dating back to 1990. The supplier was immediately instructed to implement a stress relief process to alleviate this situation.

Product improvement activity culminated with the following releases submitted during September:

- Stainless steel exhaust manifold capscrews to improve corrosion/degradation.
- New oil cooler cover gasket (foamette) to eliminate oil leakage.

Residual stress measurements were conducted on C head castings poured from 3 cavity in-mold stress relief patterns. These new patterns increase head cavities from 2 to 3 and eliminate the external stress relief process. These changes are intended to provide significant capacity improvement.

#### Edison

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The Edison C1 calibration has been finalized for the initial field test and endurance testing. The rating is 300Hp @ 2200rpm, 950 lb-ft @ 1300rpm. Activity to define the start fuel/timing and coolant advance tables is underway with limited testing in the Ford truck. Refinements in the cold cell will focus on the goal to eliminate the current mandatory requirement for the

Beru flame start for higher Hp ratings.

Collection of limit diagram data was completed. The data will be used to establish 4d timing tables and any future uprates. The data clearly indicated that 950 lb-ft is the maximum torque achievable within the current design limits.

Two of three CV field test engines have completed run-in. The first 110/100 endurance test has completed over 400 hours.

#### Elite

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The 215, 205 and 195 Hp FAPs for the 6CT Elite product were completed during September. All performance specifications met product profile with the exception of BSFC and heat rejection being above the profile goals. There are future improvements identified at this time. Improvements in low speed performance are expected as final injector nozzle optimization is completed.

The 260Hp CTA FAP development work was completed. Similar to the CT, BSFC and heat rejection were slightly above profile goal. Performance development of the 240Hp CTA with an MW fuel pump has indicated that this is achievable. This result confirms that the more expensive P3000 will only be necessary for 250Hp and above ratings.

Revision of the CT exhaust manifold (smaller flow area) has resulted in a 10% improvement in low speed performance. Production manifold designs are being finalized so that production tooling can be initiated. Production tooling must be started as soon as possible to limit usage off prototype tooling to pre-production units only.

#### Noise

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Noise testing of a 230Hp 6CTA with MW fuel pump was completed during September. This engine will be shipped to Komatsu for in-vehicle noise tests. The bare engine noise results were within 1 dBA of Komatsu's engine noise specification indicating that limited noise treatment (bedplate &/or oil pan treatment) will be required. Komatsu will evaluate the bare engine noise performance and its contribution to overall vehicle noise.

Bare engine noise emission of the automotive and industrial ratings that use the Bosch P type fuel pump are significantly higher than MW ratings due to the higher injection pressures. Activities are currently focussed on finalizing dimensions for the oil pan isolation and close fit pistons.

#### Encore

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We continue to see a growth in the number of people supporting the C encore program. Much of this growth is due to work with hardware and continued drafting workload. Additional drafting needs have been identified to support detailed drawings as well as engine and customer layouts.

The first fully machined cylinder head and blocks were received during September in support of the C1 start-up. Although these parts were acceptable,

there have been problems associated with the prototype machining of the C1 heads which has led to a significant scrap rate. Investigations to date indicate the problems is due to machining issues with the fuel return drilling and not casting related. Additional castings have been ordered to overcome the losses during the machining process.

Structural analysis activities during September were concentrated on the D Series crankshaft torsional design and split angle rod analysis.

The cylinder head FMEA was completed. The FMEA will provide input to reliability/durability test requirements for the head.

The first C1 engine build culminated with a successful startup on October 6. The engine was built with a CAPS fuel system. A lot of hard work from many areas led to this successful event.

S. C. Milloy (SEAN)

DATE: December 6, 1994  
TO : M PERRIN  
Mr. Pete Jones  
FROM: S C Milloy (SEAN)  
SUBJECT: C Series Monthly Report - November

Elite

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Major activity during November consisted of FAP development and low speed performance optimization of the CT and CTA driven in increased customer requirements.

Only 50% of the planned FAPs were completed during November. This was due to delays in receiving FAPs from Bosch, low speed optimization work, and recycle requirements based on Bosch FAP processing. The plan to complete FAPs for all ratings acknowledged as of Nov 1 by mid-Jan is still on-plan. Our ability to recover to-plan should be achievable since #1 ratings are complete, emissions mapping is complete, test cell resources have been increased, and many of the remaining ratings require only changes in governor regulation.

Low speed performance optimization was completed during November. Optimization resulted in changes in injector nozzle specification and turbocharger specification. These changes resulted in a 6-8% improvement in low speed torque, HC reduction, smoke reductions at all speeds, and reduced soot accumulation in the oil. These changes will not affect the FAP work completed or future consistency exercises.

Cold start test documentation was completed during November for the CT and CTA products. Both products exceeded the product profile goals.

Emissions compliance of the CT, CTA, and CTAA products meet NOx design targets, have achieved 50-60% of the PM standard (excellent margins), and achieved smoke levels of only 35% of the Federal smoke cycle.

Edison

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The Edison program has been cancelled. Activities are focused on documenting all valuable information as this program is closed-out.

Noise

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Field testing continues with no known issues identified to-date. Three US field engines have accumulated over 120K miles total.

Holset completed analysis and production of a range of fuel pump damper test samples during November. Testing to determine noise benefits and optimum design criteria will begin in mid-Dec with completion planned for the end of January. As an immediate measure to eliminate noise quality complaints ('knocking'), a viscous damper is released for all applications with the exception of the front barrel mount. Release has been issued to provide a new mount design that

eliminates interference between the support and the viscous damper.

#### Encore

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Support for C Encore Engineering area continues to grow at a rapid pace. For November Exempt headcount increased to 11.6 people and Hourly moved to 8.3. This increase of 6 people in the past 30 days shows the effort now being focused on the program. The re-introduction of the component teams and development of statement of work by each group has increased focus to the level which will help us succeed.

Parts have now been pulled and builds are underway for 6 engines. Shortages of some components are slowing builds. Actions are underway to expedite the remaining hardware. The push tube work continues to be run by the stress area to identify where the design need to go. Tube raw material as well as sample tubes of various sizes are due in next week.

The performance engine continues to run well in test cell 7. We are now running it on Tspec in the evenings to get additional hours of experience. to date we have run four (4) different sets of injectors. The initial design specification yielded very high smoke (4.0 Bosch at 2200rpm/250Hp). Early optimization with smaller cone angles has reduced the smoke to '94 levels at rated speed (0.6 Bosch) with approximately a 10 point improvement in BSFC over current product. Low speed smoke remains elevated. This was expected due to the much lower swirl ratio (1.9 DCS) and its compatibility with the RP43 low speed injection pressure characteristics.

S C Milloy (SEAN)